Complementary Safety margin Assessment COVRA N.V. (HABOG)

COVRA N.V.

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Contents

Summary

Based on the Belgian and the ENSREG "Stress test" specifications, an assessment of the safety margins of the facility is performed by NRG. The results of this assessment are presented in this report.

In this assessment, the response of HABOG in relation to the following topics has been evaluated:

- Earthquake
- Flooding
- Extreme weather conditions
- Loss of electrical power and loss of ultimate heat sink
- Other extreme hazards:
    - internal explosion
    - external explosion
    - internal fire
    - external fire
    - airplane crash
    - toxic gases
    - large grid disturbance
    - failure of systems by introducing computer malware
    - internal flooding
- Severe Accident Management.

It is noted that the ENSREG Stress Tests requirements were formulated for Nuclear Power Plant sites. It is therefore important to recognise the fundamental differences between a lower potential hazard site, such as the HABOG (COVRA) site, and a higher potential hazard Nuclear Power Plant site. Given the nature of the HABOG (COVRA) site, and the relatively low level of hazard posed by the activities undertaken, this document therefore presents a proportionate response to the ENSREG Stress Tests requirements. The report follows the suggested format for Stress Tests Reports, but is tailored as necessary where aspects are less significant or not applicable to the HABOG (COVRA) site.

In general, consideration of the ENSREG Stress Test requirements has concluded that there are no credible fault scenarios or cliff-edge effects at the HABOG (COVRA) site for which there are no current adequate provisions. To increase robustness of the facility additional measures are proposed in relation to potential threatening weather conditions, the emergency plan, mobile monitoring equipment and loss of power.

Introduction

Following the accident at the Fukushima nuclear power plant in Japan, the European Council declared that "the safety of all EU nuclear power plants should be reviewed on the basis of a comprehensive and transparent risk assessment (Stress test)". This review was later expanded to nuclear installations other than nuclear power plants. Based on this, the Ministry of Economic Affairs, Agriculture and Innovation (EL&I) requested COVRA N.V. to perform an assessment of the safety margins of the COVRA facility [1], based on the Belgian Stress test specifications as applied to their waste management facilities and ENSREG specifications [2][3][4]. This request was implemented by COVRA N.V. as the 'Complementary Safety margin Assessment', which results are presented in this report. The approach of the 'Complementary Safety margin Assessment' as proposed by COVRA N.V. [5] has been approved by EL&I. The underlying report is in accordance with this proposal.

Scope

In determining of the scope of the Complementary Safety margin Assessment, the Belgian stress test specifications [4] for nuclear installations as applied to their waste management facilities were followed. The Belgian Stress test states "*buildings and installations needed to be considered are buildings where possible criticality can occur and/or containing sufficient activity in case of an initiating event with a resulting accident scenario which may in theory give rise to a dose greater than 5 mSv outside the site*".

At the COVRA most of the radioactivity (> 99,9%) is contained in the HABOG. It is also the only building in which spent nuclear fuel is stored. Calculations showed that the worst possible accident scenario, concerned both design and beyond design accidents of all other buildings, results in a dose below the criteria of 5 mSv outside the site [draft Safety Report 2013]. The design based accidents could lead to a maximum dose of nearly 3 mSv, beyond design base accidents could lead to a maximum dose of nearly 4 mSv. From this follows that the scope of the assessment is determining the complementary safety margins of the HABOG.

1 General data about site/plant

1.1 Brief description of the site characteristics

HABOG, High level waste Treatment and Storage Building, is located at the site of COVRA N.V. which is situated at the east of the cities Vlissingen and Middelburg, as part of the industrial area 'Haven-terrein Vlissingen-oost' (see Figure 1.1). The site has an area of about 20 hectares.

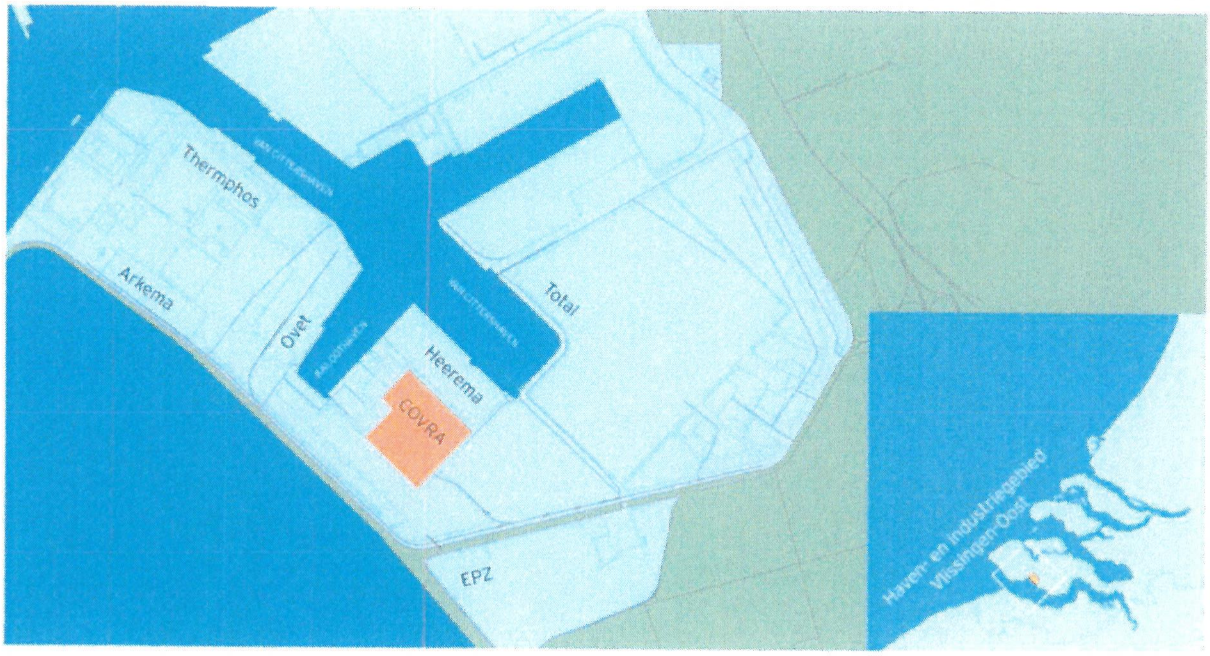


Figure 1.1 Location of COVRA site

HABOG is surrounded by several small and large companies on the industrial area 'Haven-terrein Vlissingen-oost'. The most notable company is the EPZ nuclear power plant (NPP) which is located at a distance of approximately 1km to the south-east of HABOG. The distance to the city of Middelburg is about 8 km, to the city of Vlissingen about 10 km and to the smaller villages Borssele, 's-Heerenhoek and Nieuwdorp 2 to 4 km.

On the south side is the estuary Westerschelde located. There is intensive shipping on the Westerschelde; the number of ship movements amounts to over 40,000 per year. Their origin or destination is, in many

cases, the port of Antwerp (Belgium). Included among these ships are transporters of dangerous materials, including LPG, flammable liquids and liquefied ammonia.

HABOG is located approximately 7 km from the major A-58 highway (E312). The local road is 500 m from the plant (N254). HABOG is located approximately 300 m from the nearest (main) railway line which provides service to the local ports and industries. A sideline from the main railway connects HABOG to the main railway line.

The nearest airport, Midden Zeeland Airport, is situated at about 10 km to the north of the site. This airport is intended for small civilian aircrafts with a maximum weight of less than 5.7 ton.

COVRA was founded in 1982 and since 1992 situated in Nieuwdorp, Zeeland; COVRA employs 57 people. Beside the HABOG building the other buildings at COVRA site are:

- Office building (kantoorgebouw - KG)
- Radioactive waste treatment building (afvalverwerkingsgebouw - AVG)
- The low- and medium-level radioactive waste storage building (laag- en middelradioactief afval opslaggebouw - LOG)
- Container storage building (container opslaggebouw - COG)
- Depleted uranium storage building (verarmd uranium opslaggebouwen - VOG).

De buildings of the COVRA site are shown in Figure 1.2, HABOG is highlighted in orange.

NRG

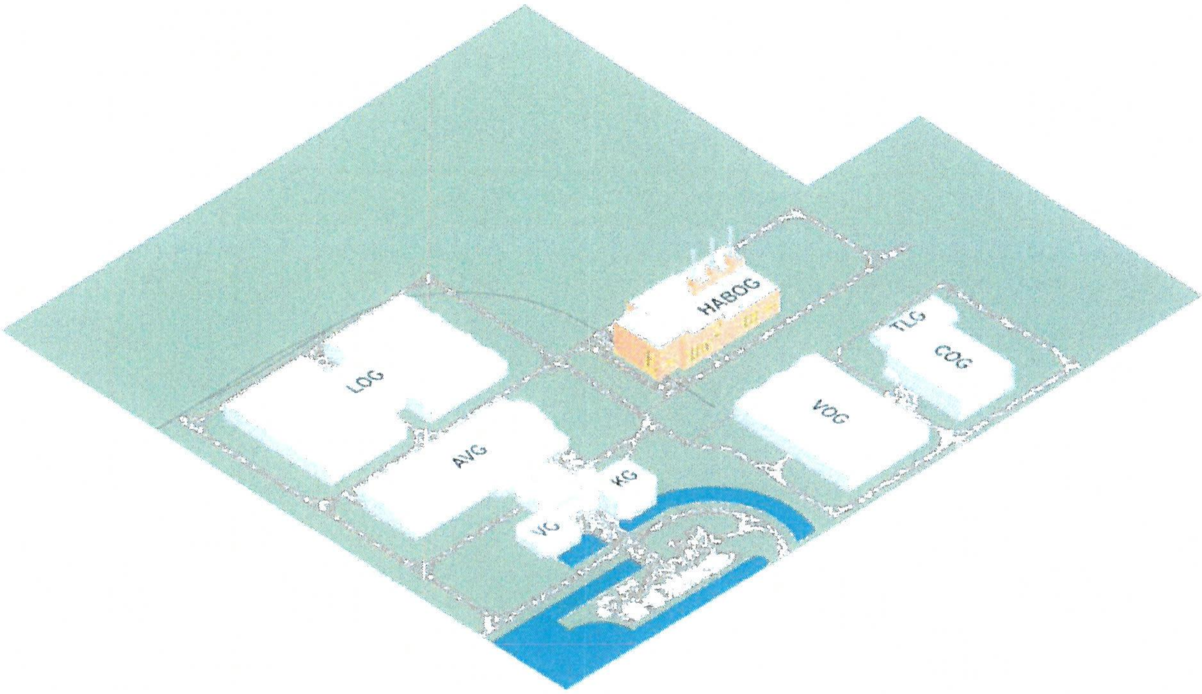


Figure 1.2 The COVRA site with the HABOG building

1.2 Main characteristics of the facility

In the center of the COVRA site the high-level radioactive waste treatment and storage building (Hoog radioactief Afval Behandelings- en OpslagGebouw – HABOG) is located (Figure 1.3). HABOG is designed for the treatment and storage of high-level radioactive heat producing waste (HPW) and non-heat producing waste (non-HPW).

The HABOG building consists of (Figure 1.4):

- A reception area (A)
- A preparation room (B)
- An unloading and packaging room (floor above C)
- Transport area (D)
- Storage room (modular compartments) for HPW (E)
- Storage room (modular compartments) for non-HPW (F).

Besides these areas, HABOG is equipped with a control room and several areas for auxiliary systems such as venting systems and energy supplies.

Figure 1.3 The HABOG facility

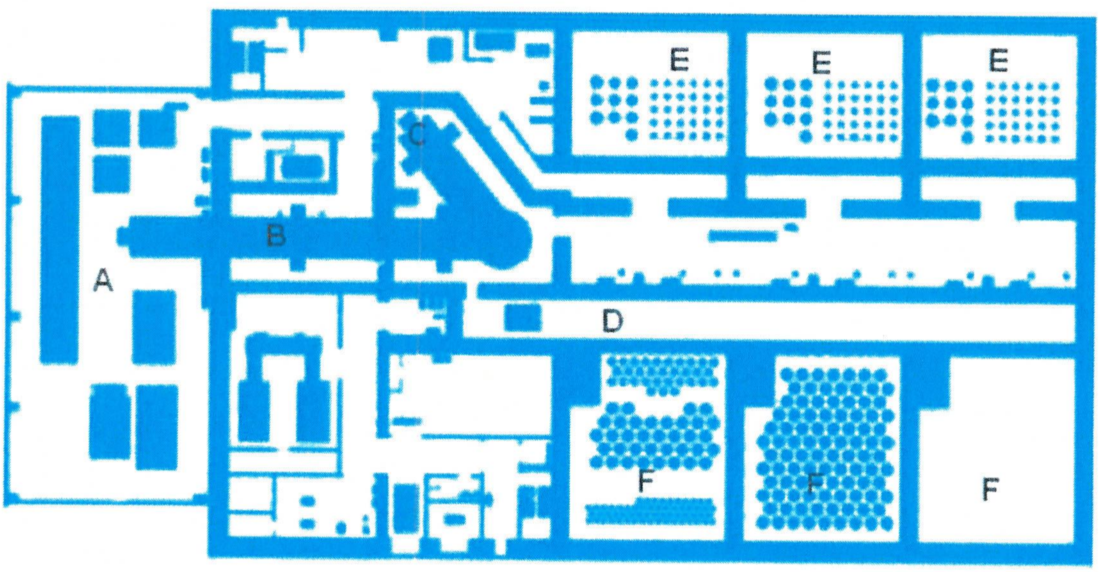


Figure 1.4 HABOG floor plan

The HPW, like irradiated fuel elements from Research Reactors (RR-HPW) and processed spent fuel (incorporated into a glass-matrix i.e. vitrified) from the Borssele NPP and GKN (V-HPW), is stored in

vertical cylindrical steel containments (wells) which are cooled by natural convection. In Figure 1.4 the three storage compartments for the HPW are located at the upper half at the right side (indicated with E). It can be observed that four well-diameters are indicated. The smallest two diameters, the smaller for standard canisters the larger for overpacked canisters, are used for vitrified waste (V-HPW). The larger diameters (the smaller for standard canisters the larger for overpacked canisters) are used for RR-HPW. In case of any leakage or damage to standard canisters, this canister can be overpacked into a large sized canister and stored in the larger well. No means are available to repair/overpack a damaged overpacked canister stored in the larger well (only possible after modifications).

Waste with (very) low or no heat production is stored in the non-HPW storage. In Figure 1.4 the three storage compartments for the non-HPW are located at the lower half at the right side (indicated with F). It can be observed in the figure that different canister sizes can be used.

For safety reasons one of the three compartments for the HPW as well as the non-HPW must be empty. In case of inspection (access to the module can be for reasons of abnormal/accidental situations) a compartment can be fully emptied by moving the waste to the third, empty compartment.

The waste in HABOG is continuously monitored by measurements and controls.

Reception area

Figure 1.5 The unloading of an MTR-2 container with research reactor fuel elements (RR-HPW)

The reception area is not part of the structure of the HABOG building and is only used for reception of the high-level waste and to transfer the waste container from the transport vehicle.

The high-level radioactive waste is delivered in transport containers by road or by rail. In the reception area the containers can be stored temporary before further treatment. After the shock absorbers of the transport container are removed (in case of Research Reactor Heat Producing Waste (RR-HPW)) and the container is checked, the container is hoisted by crane and loaded onto a trolley. The crane and the trolley are operated locally from inside the reception area.

In Figure 1.8, Figure 1.9 and Figure 1.10 the reception area is indicated in step 1 (RR-HPW) and step 1 and step 2 (V-HPW and non-HPW).

Preparation, unloading, packaging and transport

The trolley with container is driven into the preparation room. The container is checked on tightness and the atmosphere is sampled. Subsequently the bolts of the container top cover are unscrewed (lid not removed).

The transport containers are transported to the position. The top cover of the container is removed by crane. Subsequently the canisters or baskets (in case of RR-HPW) are hoisted out of the container. The baskets are hoisted from the MTR2 container into the Hot cell.

The canisters are placed on an inspection table in order to check them visually, measure the radiation and contamination and check for the identification number. After the inspection the canisters are loaded onto a trolley in the unloading area.

A part of the high-level radioactive waste is treated in the packaging area. The RR-HPW baskets (the baskets are made from neutron absorbing boron steel plates) are hoisted out of the transport container in the hotcell and placed in a canister. This canister is closed, welded, vacumised, filled with inert gas (Helium) and tested on leakage tightness. After packaging the canister is decontaminated in the decontamination area and transported to the unloading area.

The canisters with HPW are loaded onto a transport trolley which is located at the front of the shielding door of the storage room (see Figure 1.6).

The canisters with non-HPW are loaded via a hole in the floor onto another transport trolley. This transfer trolley is located in the transport area. The transport trolley is transported to the discharge position of the storage room (see Figure 1.7).

In Figure 1.8, Figure 1.9 and Figure 1.10 the preparation and unloading rooms are indicated in step 2 and step 3 (RR-HPW) and in step 3 and step 4 (V-HPW and non-HPW). In Figure 1.8 the packaging room is indicated in step 3. In Figure 1.8, Figure 1.9 and Figure 1.10 the transport area is indicated in steps 4 and steps 5.

Storage room for heat producing waste

HPW is stored in one of the three storage compartments (Figure 1.6). Several steel cylindrical wells are located in each compartment for the storage of the canisters. Five canisters are stored on top of each other in each well.

In Figure 1.8 and Figure 1.9 the storage room for HPW is indicated in steps 5.

Figure 1.6 Heat producing waste storage

Storage room for non-heat producing waste

The non-HPW (cladding material and vitrified waste from equipment for processing of NPP spent fuel) is stored in one of the three storage compartments, see Figure 1.7 where one compartment is viewed by a camera.

In Figure 1.10 the storage room for non-HPW is indicated in step 5.

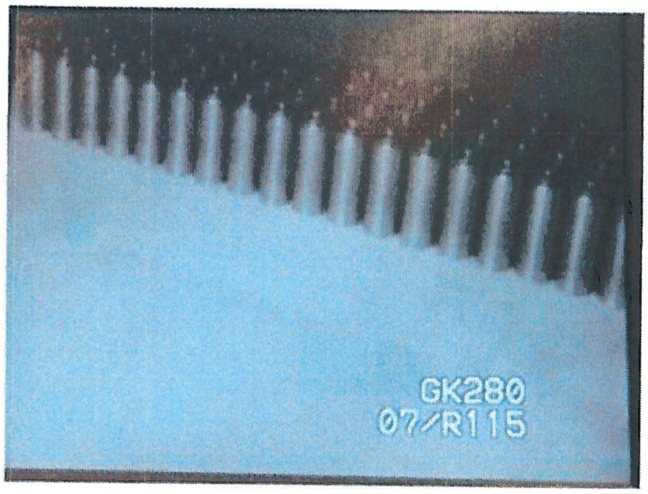


Figure 1.7 Non-heat producing waste storage

In the next three figures the three main processes in HABOG, handling and storage of V-HPW, RR-HPW and non-HPW, are summarized

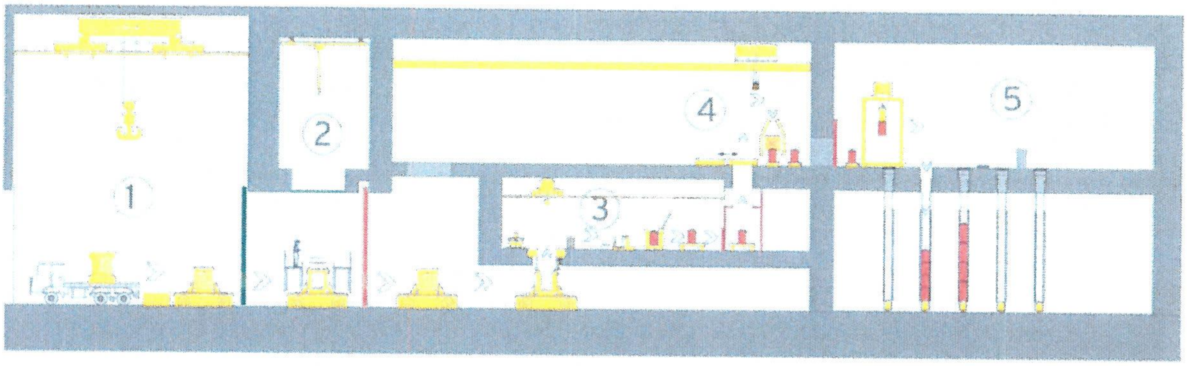


Figure 1.8 **Processing of RR-HPW**. Step 1: inspection of transport container and removal of shock absorbers; Step 2: unbolting of cover (lid not removed) and sampling for contamination; Step 3: RR-fuel is repacked in storage canisters, canisters are cleaned; Step 4: inspection of canisters; Step 5: storage in cylinder (well)

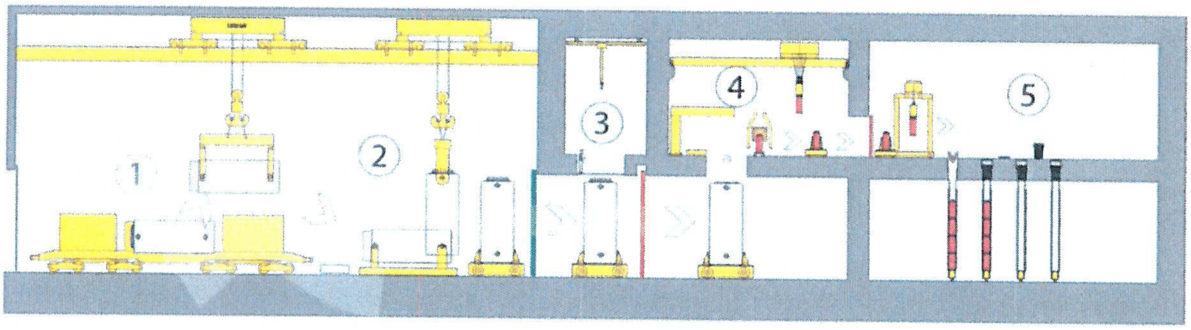


Figure 1.9 **Processing of V-HPW**. Step 1: inspection of transport container; Step 2: positioning of transport container; Step 3: unbolting of cover (cover not removed) and sampling for contamination; Step 4: unloading of transport container and inspection of canisters; Step 5: storage in cylinder (well)

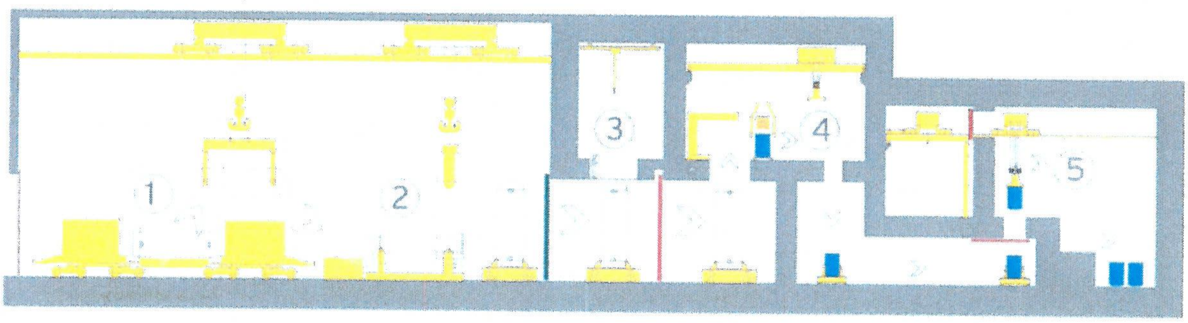


Figure 1.10 **Processing of non-HPW**. Step 1: inspection of transport container; Step 2: positioning of transport container; Step 3: unbolting of cover (cover not removed) and sampling for contamination; Step 4: unloading of transport container and inspection of canisters; Step 5: storage

Hoisting of canisters

The canisters are designed for a drop height of 8 to 9 meter (depending on the type of canister). In HABOG the height of the hoisted canisters are minimised by use of a stepped floor (see Figure 1.11). For hoisting heights above the design drop height e.g. for storage in the wells, shock absorbers are used (the height between the canister and the bottom of the well is between 10 and 11 meter) to assure containment integrity in case of accidental drop.

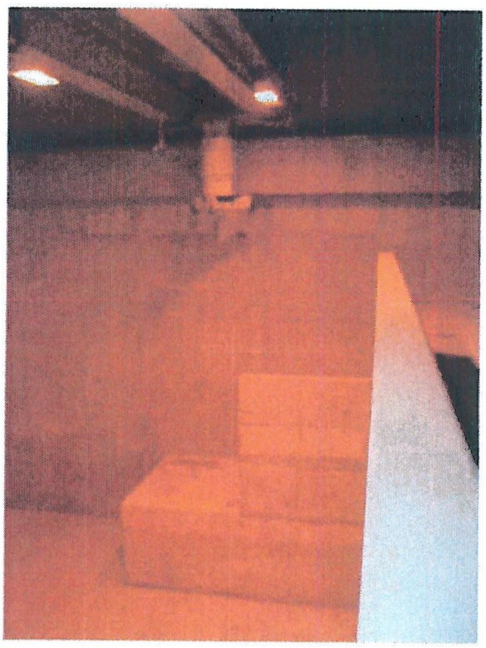


Figure 1.11 stepped floor to non-HPW storage

Main potential hazards of the facility

HABOG is a treatment and storage facility for high-level radioactive waste. This radioactive waste is stored in robust steel containers (canisters) which are placed in robust storage rooms (1.7 m thick reinforced concrete walls) with only passive safety systems. The main potential hazards relating to the storage of the radioactive waste in HABOG are:

- Release of radioactivity during fault conditions
- Criticality arising from a fault condition.

1.3 Fundamental safety functions

There are significant differences between the fundamental safety functions and support functions required for higher potential hazard NPP operations compared with the lower potential hazards posed by operations at the COVRA site. For NPPs, the three fundamental safety functions are:

- Control of reactivity
- Fuel cooling
- Confinement of radioactivity

and the key support functions are:

- Power supply
- Cooling through the ultimate heat sink.

The HABOG facility contains heat producing waste from or derived from spent reactor fuel. Decay heat removal systems are therefore still relevant for the HABOG facility despite of the fact that the decay heat from the heat producing waste is significantly lower than the amount produced in a NPP. The heat removal in the HABOG facility occurs in a passive way. Therefore, on the contrary to NPP's, the power supply is not a key support function for the HABOG facility.

The three fundamental safety functions, control of reactivity, fuel cooling and confinement of radioactivity, and the key support function cooling through the ultimate heat sink are captured in the following three safety functional requirements:

- Prevent criticality
- Prevent loss of cooling
- Prevent radioactivity release.

HABOG design considers initiating events from both natural and man-made external hazards, including seismic, extreme weather (including flooding), gas cloud explosion and aircraft crash. Safety measures are identified based on the possible consequences, including those arising from the potential for criticality, loss of cooling and radioactivity release.

The assessment of risks for HABOG considers those arising during normal operations and fault conditions through a systematic identification and assessment process. The overriding objective for the

safety of HABOG is the elimination of hazards, by designing in inherent safety. Where this is not practicable, suitable and sufficient safety measures are identified to deliver the safety function following an initiating event.

Engineered Structures, Systems and/or Components (SSC) are employed to deliver the safety functions wherever practicable together with robust procedural controls. There is adequate redundancy to accommodate single random failure and to minimize the likelihood of dependent failures. The design of plants, processes and operations is based on appropriate levels of defence in depth including diversity and physical separation.

1.3.1 Reactivity control

In HABOG spent fuel is stored. Unlike NPPs, which require shutdown mechanisms to achieve sub-criticality, the safety aim during treatment and storage is to never achieve critical conditions. In fact under all credible conditions, systems shall remain subcritical by a fair margin.

Criticality is only an issue for storage of spent fuel or spent fuel containing waste. The conditions for criticality are a combination of:

- Available mass of radioactive material
- Enrichment percentage of the radioactive waste
- Geometrical conditions
- Presence of a moderator like water, hydrogen or carbon.

The following applies for the HPW in HABOG. Even in the presence of a moderator (like water) the effective multiplication factor k_{eff} is always below the criticality safety criterion of 0.95, due to a prescribed storing geometry. So for accident situations whereby water replaces the inert gas in the HPW wells as well as in the RR-HPW canisters, criticality does not occur (analyzed by ECN/NRG).

1.3.2 Cooling Requirements

Due to the storage of heat producing waste (Figure 1.12), decay heat removal systems are necessary for HABOG. However, the decay heat at the COVRA site is significantly lower than the amount produced in a NPP.

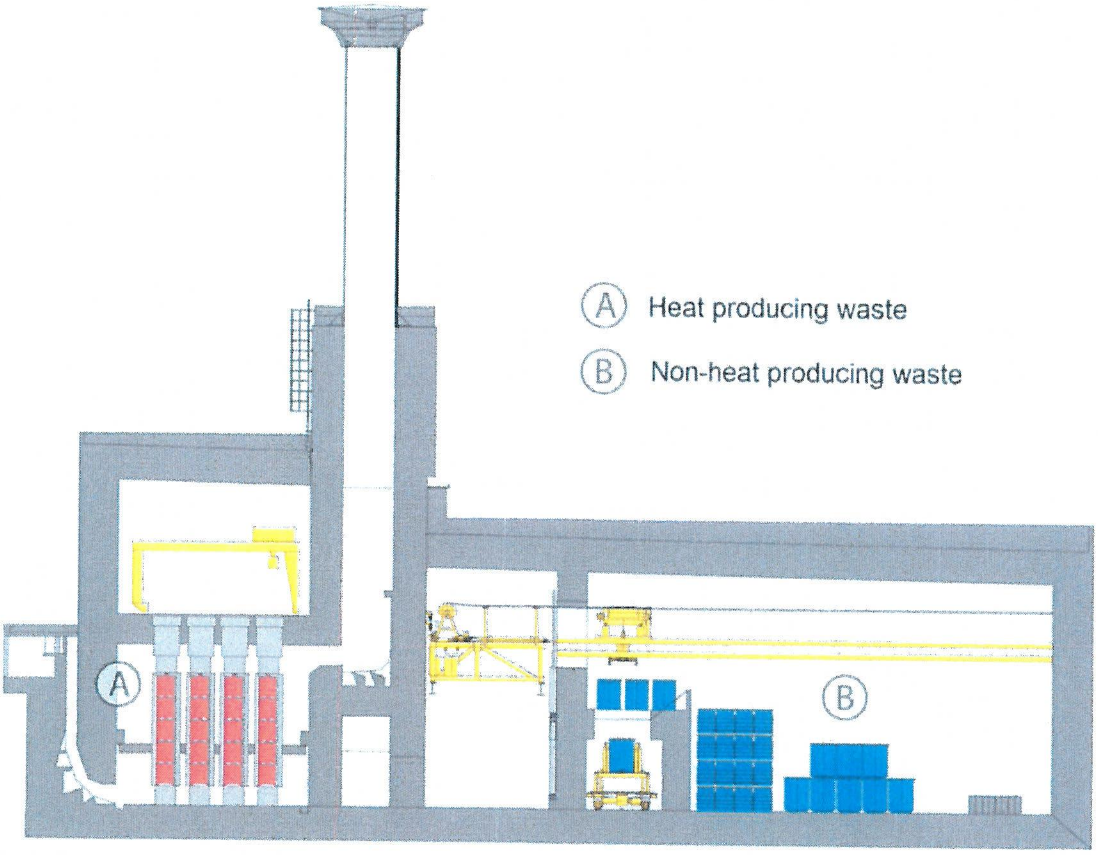


Figure 1.12 Storage of heat producing waste and non-heat producing waste

The ventilation system of HABOG consists of a natural convection system for the cooling of the heat producing waste (Figure 1.13) and a mechanical ventilation system for the ventilation of the other treatment and storage rooms. The mechanical ventilation system is not necessary for cooling but mainly for ventilation and filtering of the air. The mechanical ventilation does not support the cooling safety function of the HABOG facility.To maintain the storage of the heat producing waste within the safety boundaries, i.e. below the limit temperatures, cooling by natural convection of the heat producing waste is required.

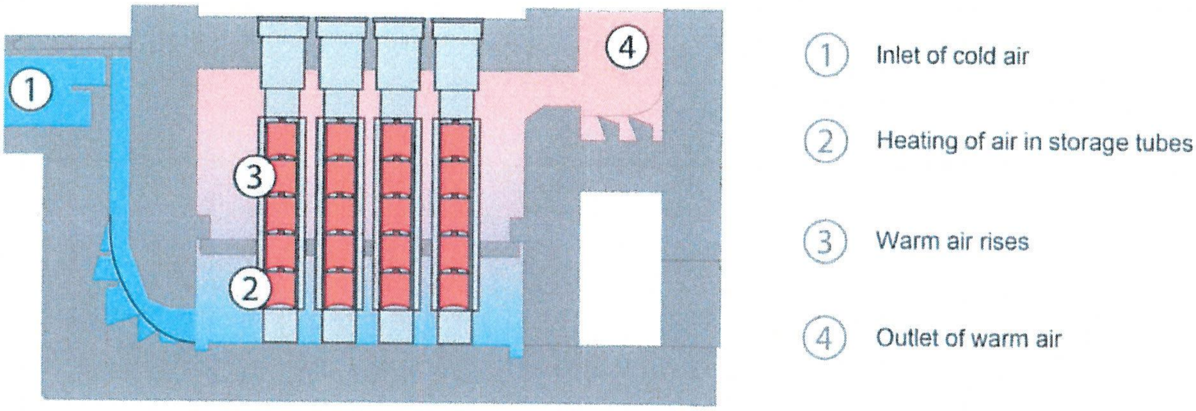


Figure 1.13 Natural convection system for the cooling of heat producing waste

The natural convection system is designed in such a way that the maximum allowable temperatures of the heat producing waste and construction materials are not exceeded during normal operation, malfunctions or accidents. The maximum allowable temperatures are shown in Table 1.1 for normal operating conditions and

Table 1.2 for accidental conditions.

Table 1.1 Limit temperatures for storage of HPW for normal operating conditions

	Limit temperature (°C)
V-HPW (in center canister)	500
Fuel element (cladding)	250
Concrete construction	95 (locally 105)

Table 1.2 Limit temperatures for storage of HPW for accidental conditions

	Limit temperature (°C)
V-HPW (in center canister)	610
Fuel element (cladding)	425
Concrete construction	180

The maximum occurring temperatures in the storage room are calculated with a validated model. The results for the V-HPW are given in Table 1.3. The results show that the calculated temperatures are lower than the specified limit temperatures in Table 1.1. Due to conservative assumptions (like intake air temperature) and decrease in heat production due to decay, temperatures in the storage room/HPW are lower in practice.

Table 1.3 Maximum temperatures for V-HPW waste during storage (decreasing in time due to decay)

	Temperature (°C)
Intake Air	27
Casing pipe	97
Containment (steel cylinder)	180
V-HPW (in center canister)	460
Exhaust Air	56
Concrete construction	78

Similar calculations are performed for fuel element temperatures (RR-HPW). The calculations show that the fuel element temperatures are lower than the specified limit temperatures in Table 1.1.

Calculations show that even with a 95% blockade of the air inlet, the maximum temperature for normal conditions, Table 1.1, of the V-HPW is not exceeded. Even in case of a full blockade of the air inlet, temperatures stay below limit temperatures for normal operating conditions for a long time (several months, estimation based on KEMA calculations). The situation of a fully blocked air inlet for a long period can be considered as highly unrealistic.

1.3.3 Confinement of Radioactivity

In the HABOG facility high-level radioactive waste is stored and separated from the environment. For the confinement of radioactivity of the high-level radioactive waste there are several containment barriers, as described below.

The spent fuel of the KCB is recycled in France and the remaining fuel material is immobilized in a glass matrix (V-HPW). The spent fuel from research reactors is delivered in baskets. The aluminum cladding forms the solid matrix for this type of waste (RR-HPW). The mentioned matrices form the first containment boundary. This immobilized waste is stored in canisters, forming the second containment boundary (Figure 1.15). The RR-HPW canisters are filled with an inert gas (Helium). The third containment boundary is formed by the cylindrical steel wells (Figure 1.14) in which the canisters are stored; in total five canisters can be stored in one well. The well is locked with a shield plug and filled with an inert gas (Argon) to protect the canisters from corrosion. The integrity of the canisters and wells are periodically tested by gas detection measurements.

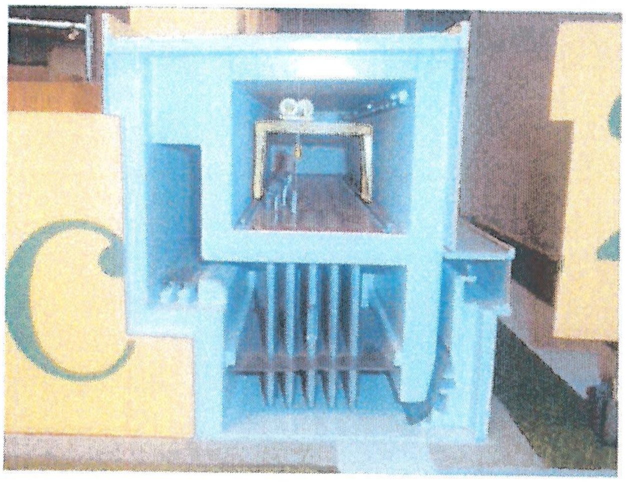


Figure 1.14 Cylindrical wells for storage of HPW (scale model)

Figure 1.15 Canister for V-HPW

The non-heat producing waste, mainly cladding material from NPP fuel and used equipment for waste processing, forms a solid matrix. The non-HPW is stored in canisters, forming the first containment boundary. These canisters are placed in ventilated and filtered compartments of HABOG which serves as a second containment. The mechanical ventilation system is designed in a way that the air flows from (potentially) less or non-contaminated areas to (potentially) more contaminated areas. The ventilated air is filtered before it is released.

For a (significant) release of radioactivity to occur following severe damage, one or more of the following would need to occur:

- Significant damage to canisters to cause release (for both waste types)
- Significant damage to cylindrical wells (for HPW)
- Significant damage to ventilation and monitoring systems (for non-HPW).

1.3.4 Power supply

The power supply system is important for HABOG operations but provides no support to nuclear safety functions. All systems required for supporting the safety functions have a passive safety design. All other processes are designed to shut down in a safe manner following loss of power.

HABOG is connected to the 10kV external grid via a transformer. There are separate main distribution rails for the normal and essential power supply. These distribution rails are physically separated.

When a single electrical subsystem fails, power can be supplied by connections with other power supply (sub)systems to provide power to the essential parts of the installation. In case of loss of off-site power (10 kV) or a failure of the transformer, the emergency power supply system (emergency diesel generator) delivers the electricity required for the essential power supply for HABOG.

In the transitions to emergency power supply the normal power supply is disconnected from the lighting and other normal electricity users. The essential users are subsequently connected to the distributor of the emergency diesel generator.

The electrical installation is provided with a static no-break installation for the uninterrupted power supply (UPS) of measurement and control systems. The UPS has a capacity sufficient for 5 hours.

1.4 Scope and main results of Probabilistic Safety Assessments

No PSA has been carried out for HABOG. A risk evaluation of HABOG is currently under development as input for the new Safety Report. It is anticipated that this risk evaluation will show that the Dutch risk criteria will be fulfilled.

2 Earthquakes

2.1 Design basis

2.1.1 Earthquake against which the plant is designed

The area of the Netherlands has low seismic activity. Most activity is located in the south-east part, as can be seen in Figure 2.1 where the size of the spots indicate the magnitude of historic earthquakes

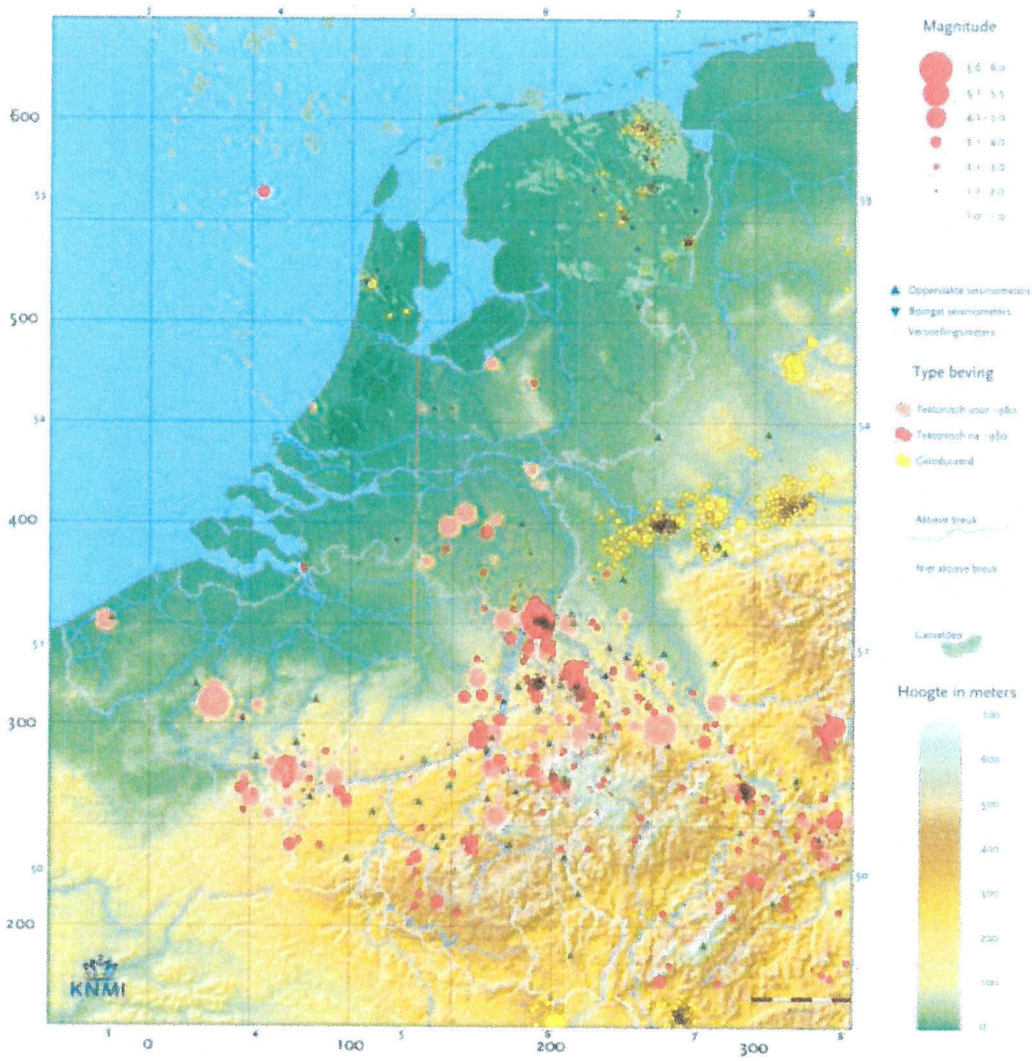


Figure 2.1 Earthquakes in the Netherlands in the period 1904-2004

(yellow spots indicate induced seismic activities, the dark red spots indicate tectonic activity before 1980 and light red spots indicate tectonic activity after 1980). It can be observed in the figure that in the last century no seismic activity took place in the region of Vlissingen. The highest earthquake intensity ever recorded in the area near this region is V½ MMI (Modified Mercalli Intensity), caused by the earthquake with a magnitude of 5.6 on the Richter scale near Tournai, Belgium on June 11, 1938.

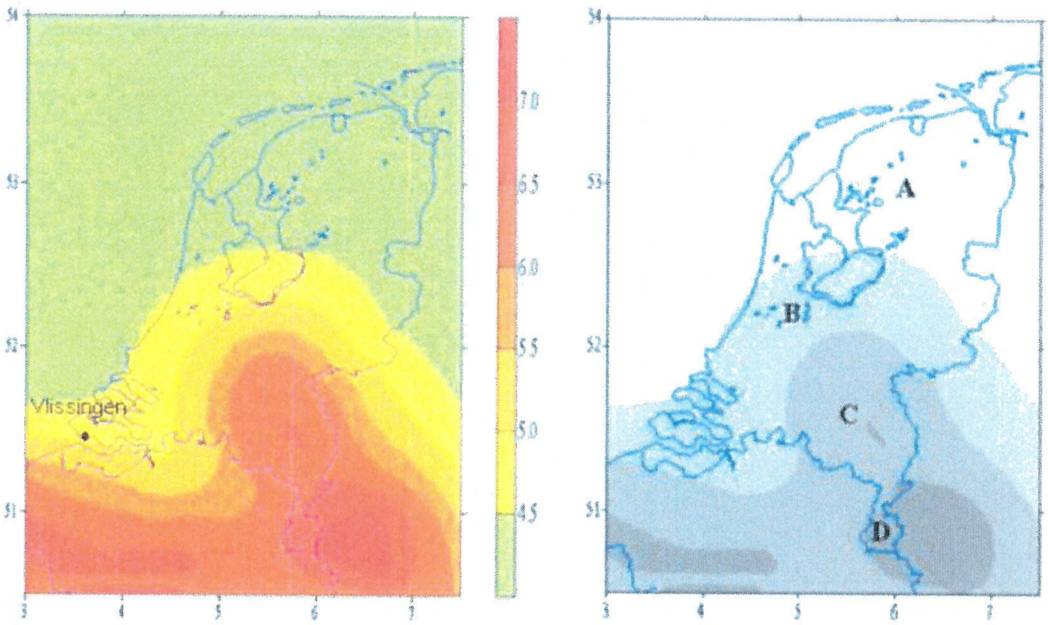


Figure 2.2 Seismic zoning map in EMS (left) and PGA (right)

The COVRA site lies in a zone with low seismic potential. In Figure 2.2 seismic zoning maps for the Netherlands are shown for tectonic seismicity with a 10% probability of exceedance in 50 years (return period 475 years), given in European Macro-seismic Scale (EMS) and converted into peak ground accelerations (PGA). The indicated PGA zones have the following values:

- Seismic Zone A: PGA = 0.10 m/s^2 (0.010 g)
- Seismic Zone B: PGA = 0.22 m/ s^2 (0.022 g)
- Seismic Zone C: PGA = 0.50 m/ s^2 (0.050 g)
- Seismic Zone D: PGA = 1.00 m/ s^2 (0.100 g).

These PGA values occur not at ground level, but at the interface between the Holoceen and Pleistoceen geological layers.

According to this categorisation the COVRA site falls into seismic zone B, which means that a PGA of 0.022 g could be applicable to this region.

Concerning induced earthquakes it can be concluded that no induced earthquakes have taken place nor are they to be expected because no oil and gas extraction takes places in this region.

Site specifics

In the recent geological epoch, the Holocene, in the western part of the Netherlands deposits occurred which can be tens of meters thick in the coastal areas. In Walcheren and Zuid-Beveland the surface sediment exists of "young clays and sands". As a result of tidal movements, which had effect before embankments took place, there is also a relatively low relief of 1 to 1.5 m.

The topsoil of the site consists of raised sand. Underneath is a thin layer of clay, which formed the previous cultivation layer. Below is a mixed package of sand with various kinds of layers. At a depth of about 22 m -NAP to 28 m -NAP, a very dense sand layer is present.

Research that was conducted by Delft Geotechnics for the location shows that the maximum intensity in the area around the location could be approximately VI½ on the Mercalli scale. The corresponding horizontal (free field) peak acceleration is about 1 m/s^2 (0.1 g), the concurrent vertical peak acceleration amounts to 2/3 of the horizontal acceleration. The probability of this type of earthquake is 10^{-6} per year (so a return period of a million year). The probability per year of exceeding horizontal peak accelerations, applied to the COVRA site, is given in Figure 2.3. The motion duration for the different types of earthquakes (accelerations) is less than 5 seconds.

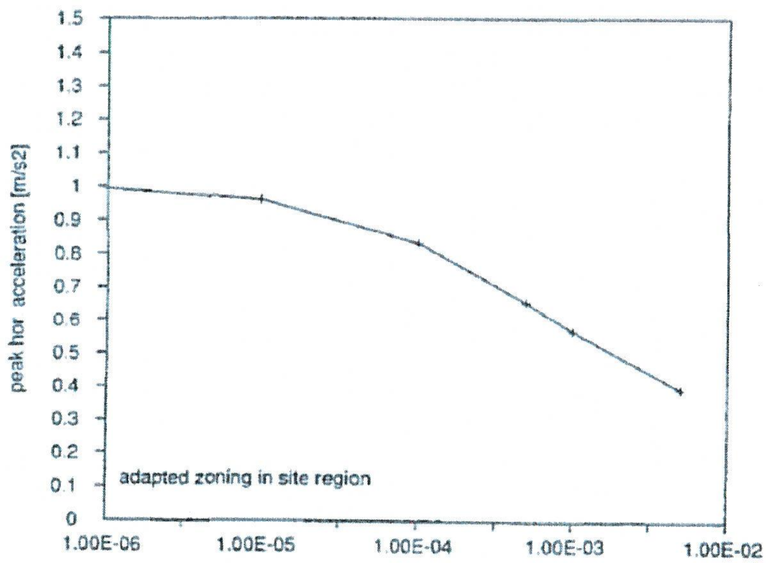


Figure 2.3 Probability of exceedance per year (X-axis) vs. horizontal peak acceleration (Y-axis)

The occurrence of possible liquefaction at the HABOG site is evaluated by Delft Geotechnics (1996, as part of the Dynamic Geotechnical Analysis of the Detailed Design by HBM-HBW). The final conclusions

of this evaluation "with respect to liquefaction are that this is unlikely to occur, and that any geotechnical effect will be harmless for the structure".

For the construction of HABOG soil improvement has been applied. The terrain has been excavated up to about 0.5 m + NAP. This soil was a mixture of clay and sand. The excavation has been filled up with sand up to a ground level at approximately 5.6 m + NAP. Due to this the surface is considered as sufficiently stable.

Design requirements
The HABOG facility, more specific the building and safety relevant equipment and infrastructure, is well designed against earthquakes. HABOG is designed for a PGA of 1 m/s^2 (or 0.1 g; this value is indicated as the Design Basis Earthquake (DBE)) and meets the Dutch requirement NVR 3.1. NVR 3.1 requires:

- design against the maximal ground movement at the site with a probability of 10^{-6} per year
- development of a site response spectrum based on local geological information
- no building on fractures in earth layers below the buildings
- maintaining the fundamental safety functions in case of occurrence of the maximal ground movement.

In addition to the design criteria according to NVR 3.1, the loading capacity and stability of the building, with the exception of the reception area and the stack, are ensured. The latter are designed according to the current NEN standards (NEN normen). The stack has a break point which, in case of a break, results in an acceptable stack height regarding thermal aspects.

2.1.2 Provisions to protect the plant against the design basis earthquake

The plant's protection against earthquakes is based on defence in depth. The first level of defence aims at preventing the challenge to the building and (safety) systems due to earthquakes. This prevention is firstly established by proper site selection. As described above, the site is characterised by a very low seismicity. Secondly, prevention is provided by an engineered design of all SSCs supporting normal and emergency operation herewith maintaining the fundamental safety functions. For preventing radioactive release, loss of cooling and criticality (safety functional requirements, see chapter 1), the following provisions for earthquake protection, are foreseen:

- Confinement: the waste has several confinement layers starting with the waste matrix (all solid), package, storage containment (e.g. cylinders) and building (wall thickness: 1.7 m). The canisters

are well designed against external forces to prevent loss of integrity. Therefore, the integrity for the canisters are ensured for a drop height of 8 to 9 meter.
The transport containers for road and rail transport meet the requirements of the ADR (European convention concerning the transport of dangerous goods over land) and the IAEA TS-R-1. The containers are designed to withstand severe conditions that are postulated for rail and road transport (such as high temperatures and high impacts). A transport container can withstand temperatures of 800°C for at least 30 min and a drop height of at least 9 m (in practice it turns out to be much more, e.g. for a type TN17/2 container much more time, ~6 hour, at 800°C or container drop height, ~30 meter, is necessary to damage the container in a way that radioactive releases are possible).

- Cooling: natural convection via air inlets in the building. The building is designed for earthquakes occurring once per million years (DBE). After occurrence of a DBE, structures, systems and components will be intact. The passive cooling system will function because no blockage or (relevant) damage to air openings will occur. The stack is only designed according to current NEN standards (NEN normen). Damage to the stack does however, also due to the designed breaking points, not threaten the passive cooling and does not threaten the main concrete constructions.
- Criticality: due to the design of the waste matrix, the amount of waste per package and the packaging materials and dimensions, subcriticality is ensured for the waste stored in HABOG. Possible effects of an earthquake, for instance falling of canisters or denting, will not have an effect on the subcriticality level in the waste.

The functions maintaining nuclear safety in HABOG are all passive. No support (for instance electricity or water) is needed to maintain these functions. However, electricity is needed for monitoring and control. In case of loss of off-site power (LOOP) due to an earthquake, emergency power will probably take over control of relevant systems like ventilation, room monitoring and, when necessary, hoisting equipment. The emergency power equipment is not formally seismic qualified, however, all emergency power equipment/parts are secured to the floor so the system cannot be damaged by falling parts.

Loss of power is further described in chapter 5.

2.1.3 Compliance of the plant with its current licensing basis

HABOG compliance with its current licensing basis is laid down in the Safety Report (VR). HABOG has a maintenance system and operating procedures to ascertain the proper functioning of structures, systems and components. The safety settings are included in the Technical Specifications.

No specific measures and procedures exist for earthquake situations, nor are these deemed necessary. As there are no procedures and processes to deal with earthquake situations, there are no procedures that deal with mobile equipment and supplies that are planned for use.

2.2 Evaluation of safety margins

2.2.1 Estimation of safety margin against earthquake

For HABOG neither a seismic PSA nor an explicit Seismic Margin Assessment has been performed in the past. A qualitative evaluation of the seismic margin is described below.

A seismic margin of a facility or plant is generally understood to be the capability to withstand seismic loads exceeding the design basis. If these margins are to be expressed quantitatively, it is necessary to describe the facility's seismic capacity in terms of representative ground motion parameters. The use of the peak ground acceleration (PGA) as a characteristic ground motion parameter found the widest application and is also used for HABOG seismic evaluation.

The following describes the approach to seismic design and consequential uncertainties:

- The seismic capacity cannot be expressed easily as a discrete figure since there are various sources of variability (due to randomness and uncertainty). It is common practice to express the seismic capacity either as median seismic capacity A_m, i.e. the 50-percentile of the variability distribution, or as HCLPF (high confidence low probability of failure) capacity. The HCLPF thus represents the peak ground acceleration at which the probability of seismic induced failure level is low (< 5%) at high confidence (= 95%). HCLPF values can be elaborated for individual SSCs but also for safety functions and the entire facility. Often there are different success paths ensuring a safety function (the seismic capacity of a safety function is then determined using the MIN-MAX rule: the minimum seismic capacity of the SSCs required in each success path is first derived, then the HCLPF capacity of the safety function is given by the maximum capacity of each success path).
- Choice of ground motion characteristics: ground floor response spectra used in the verification study of the seismic adequacy are design spectra, i.e. the spectra have been subject to smoothing

and broadening. In particular, this introduces a substantial artificial increase of energy content of the excitation.

- Conservatisms in determining the seismic demand: earthquakes induce oscillations to a chain of different oscillators at a site, starting from the soil, the base plate and the upper floors of buildings up to smaller pieces of equipment. These different oscillating sub-systems show more or less significant interaction effects. For example, the heavy weight of the HABOG building has a damping effect on ground oscillations. Similarly heavy equipment installed inside dampens the vibrations of the supporting floors. A realistic description of this complex oscillation behaviour would therefore require modelling the entire system and considering nonlinear effects as well, such as plastic deformation.
- Conservatisms in determining the resistance to seismic loads: e.g. application of safety factors following the relevant codes, use of conservative material properties, neglecting plastic deformation capability.

Due to application of several conservatisms in the seismic design of the SSCs of the HABOG facility, the seismic capacity is expected to be (much) higher than expressed by the DBE. The HABOG building has very thick (1.7 m) reinforced concrete walls. When exceeding a DBE only limited damage to SSCs may occur. The possible consequences for the fundamental safety functions are described below.

<u>Confinement of radioactivity</u>

Due to the Beyond Design Basis Earthquake (BDBE, exceedance of DBE), canisters for Non-Heat Producing Waste (non-HPW) may fall onto the ground. The canisters are well designed against external forces and integrity of the canisters will not be lost due to such a fall, and the confinement layers stay all intact. After the earthquake, enough time is available to restore or, when deemed necessary, repack the canisters. Inside the HABOG building enough (no power using) equipment is available to replace dropped canisters so they can be inspected, operated and restored.

The non-HPW canisters are not fixated between walls or other solid borders. So the canisters cannot be crushed due to moving walls caused by an earthquake.

For the Heat Producing Waste (HPW), the cylindrical wells may be damaged after a BDBE, possibly leading to escape of inert gas (Ar) which is inside the cylinders. The integrity of the canisters will not be lost. After the earthquake the canisters can be removed and stored elsewhere (in the unloading room a storage well for canisters is available; a canister can also be stored in a transport container). The third, empty, compartment may be used to store canisters from damaged wells.

It is possible that parts of the ventilation systems are damaged or due to failure of emergency power ventilation have stopped. Consequences are a very slow build-up of noble gases, hydrogen gas and possibly some aerosols in the non-HPW storage room. Due to the loss of under-pressure in the storage room, these substances will spread slowly over other rooms in the building. Possible cracks in the building walls (due to the BDBE) are expected to be minor, and will not result in an open connection to the environment.

When operating welding activities during a BDBE in the hot-cell, damage to the welding equipment could be expected. Assuming damage to this equipment, the unfinished cover of the canister is not gas tight, so the fuel matrix is in contact with the hot-cell environment. The radioactive material is however still confined by the hot-cell and HABOG building. After the earthquake enough time is available to find solutions for finishing packaging activities (e.g. overpacking).

The reception area may be significantly damaged. Parts of the 18 meter high roof may fall on a transport container. Compared to the impact of a container drop from 9 meter height, the limited mass of falling roof parts will not significantly damage the transport container (i.e. no damage causing a release of radioactive products).

Cooling of the waste

Cooling of the HPW is ensured by natural convection. The stack may be damaged after a BDBE. A study of KEMA has shown that blockage of the air ducts of 95% (so 5 % of the air passing area is available), cooling is still sufficient and normal temperature limits are not exceeded. Even in the case of a full blockade of the air inlet, temperatures stay below limit temperatures for normal operating conditions for a long time (several months, estimation based on KEMA calculations). So confinement of the V-HPW is not threatened by blockage of the air inlet. It can be remarked that it is not realistic that the air inlet will be fully blocked, or even blocked at all, for a period of several months.

Control of Reactivity

The subcriticality level is not threatened by the BDBE. This is due to the fact that serious damage to canisters is not expected.

Conclusion

Due to application of several conservatisms in the seismic design of the SSCs of the HABOG facility, the seismic capacity is (qualitatively) estimated to be (much) more than expressed by the DBE. Exceedance of the DBE may result in small damage to SSCs, but will not threaten the fundamental safety functions.

It can be concluded that an extreme earthquake does not lead to cliff-edge effects.

2.2.2 Earthquake exceeding the design basis earthquake for the plant and consequent flooding exceeding design basis flood

In general, an earthquake at sea may cause a tsunami, which in turn may cause a flooding. In this case, a tsunami formed in the North Sea will not grow to high amplitudes, due to the relatively shallow water. A tsunami formed at greater depth at sea must travel a far greater distance through e.g. the North Sea or the Street of Dover to reach Vlissingen-Oost which will decrease its amplitude to a negligible magnitude. See chapter 3 for more information on tsunamis.

In conclusion, a beyond design basis earthquake is not expected to lead to external flooding of the COVRA site.

2.2.3 Measures which can be envisaged to increase robustness of the plant against earthquakes

The occurrence of earthquakes exceeding DBE is highly unlikely ($< 10^{-6}$ per year). Taking this into account in combination with the limited consequences when exceeding the DBE, no measures are proposed to increase robustness of the facility.

3 Flooding

This chapter describes the outline of the analysis of the COVRA site with respect to flooding conditions. The flooding conditions considered are inundation by the "Westerschelde", which covers flooding due to extreme rain fall.

3.1 Design basis

3.1.1 Flooding against which the plant is designed

Not all parts of the Netherlands are above sea level. This can be observed in Figure 3.1, where the colored parts indicate the height level below or above NAP (*Normaal Amsterdams Peil,* an indication of the mean sea level). Green parts show the regions below NAP, the yellow/brown parts show the regions above NAP. The red circle (in the south west) indicates the location of the COVRA site. It can be noticed that the site lies in a region just above sea level (yellow color).

Figure 3.1 Height map of the Netherlands with respect to N.A.P.

However, the COVRA buildings, including HABOG, have a ground floor level at approximately 5.75 m + NAP. The level of the site area is approximately 5.60 m + NAP. The site is located outside the dikes.

Nuclear Base Level (NBP)

In 1980, the Nuclear Base Level (in Dutch: Nucleair BasisPeil, or NBP) was introduced. The NBP results from the requirement that a nuclear facility should be protected against external

hazards in such a way that the probability of an accident with serious consequences caused by external events - in this case floods - will be small compared to the risk of serious accidents originating from causes within the facility itself. This requirement is met if the safety measures are such that an external event with a return period of 1 million year (frequency of 10^{-6} per year) can be withstood. The NBP is determined for the location Vlissingen-Oost at 6.75 m + NAP.

Nuclear design level (NOP)

For flood-resistant design of a nuclear facility, a nuclear design level is obtained by adding various factors to the NBP, as defined in the regulations of the IAEA. The resulting level (NBP + factors) is the calculated nuclear design level (in Dutch: Nucleair OntwerpPeil, or NOP). The NOP for the HABOG site is defined as the NBP, with the addition of the following:

- Compensation for rising sea level : + 0.66 m
- Local wind effects : + 0.75 m
- Long waves (Seiches): + 0.30 m
- Wave top size: + 1.50 m.

The resulting NOP is therefore 9.96 m + NAP. HABOG, more specific, the non-HPW, HPW storage rooms and unloading/packaging room, is designed for this flood level. This means that the reception area, the preparation room and transport area can be flooded at a lower level (from +5.75 m NAP).

Tsunami

In a study carried out in 1993, it was concluded that a hypothetical tsunami would result in a maximum elevation of the water level of 1.4 m along the Dutch coast. Based on this conservative assumption, the risk of flooding due to a tsunami is regarded as non-existent, because a tsunami combined with the most extreme recorded storm surge (4.7 m + NAP, 01/02/1953) would result in a water level of 6.1 (1.4 + 4.7) m + NAP, which is still below the NOP of 9.96 m+ NAP [6].

This conclusion is supported by more recent research. In 2007 a study concluded that Cuxhaven (German Bight) is protected from the catastrophic impacts of a hypothetical tsunami of 0.5 m. As far as the Belgian coast is concerned, research concluded in 2005 that a hypothetical tsunami will not grow to an amplitude of several meters but to a maximum of 0.7 m, due to damping in the relatively shallow North Sea. This makes a tsunami, in the first approximation, of the same order as the 1953 storm surge. Therefore it was concluded that the Belgian coast, including the Westerschelde, is at a lower risk of a potential tsunami compared to other extreme meteorological effects. This conclusion was confirmed in a recent benchmark with NPP Doel (Belgium) [6].

Extreme rainfall

Heavy rainfall may cause flooding. The average annual rainfall between 1961 and 1990 was 731.2 mm. Statistics from the KNMI show that, for the area of Vlissingen-Oost, 108 mm of rainfall can be expected within a period of 24 hours once every thousand years (10^{-3} per year). Under the same conditions, 123 mm of rainfall can be expected within 48 hours. In the climate scenarios given in KNMI '06, the worst-case scenario of expected rainfall within 24 hours by the year 2050, predicts an increase with 19 mm. The largest amounts of rainfall within 24 hours measured in the vicinity of the COVRA site in the period 1951-2010 were approximately 81 mm at Vlissingen and 93 mm at Schoondijke.

For the site to flood up to a level of NOP an unrealistic amount of rainfall (thousands of mm's) would be required. Therefore, based on the statistics mentioned, such an event is not considered credible. The influence of extreme rainfall on the integrity of structures of the facility is treated in Chapter 4, Extreme Weather.

Soil surface HABOG site

When the site area is flooded the risk exists of erosion (due to the passing water and waves) of the soil surface surrounding HABOG. Soil erosion can cause instability of the foundation due to under-flushing. A study of Rijkswaterstaat (1993) showed that the protection of the soil surface around the building by gravel/stone or turf is sufficient to prevent under-flushing of the HABOG building. The turf layer is 20-30 cm thick.

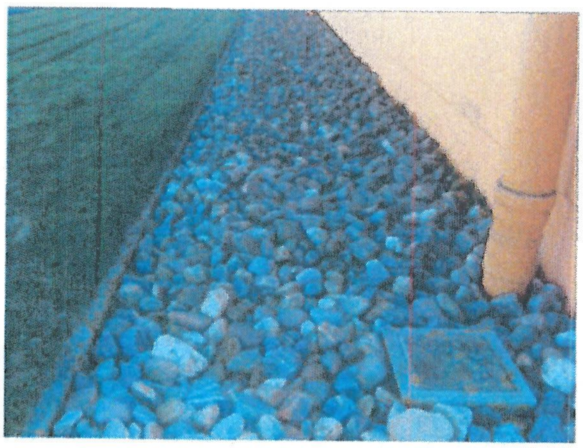


Figure 3.2 Turf and stone surrounding the HABOG building

Conclusion on the adequacy of protection against external flooding

HABOG is designed for flooding for the nuclear design level of 9.96 m +NAP. For this level the probability of flooding is 10^{-6} per year. The design level for flooding takes into account the effects of sea level rise, local wind and wave effects.

NRG

The soil surface around the HABOG building is capable of preventing the building for under-flushing.

3.1.2 Provisions to protect the plant against the design basis flood

The SSCs and provisions are sufficient to maintain the three fundamental safety functions confinement, cooling and sub-criticality in case of at least design basis flood (NOP, 9.96 m + NAP).

The concrete constructions of HABOG are designed to prevent the waste for water contact by ground water and inundation for a flood level of at least 9.96 m +NAP (NOP). The storage room for non-HPW is protected for a flood height of 10.75 m +NAP, which is indicated (room 118) in the left part of Figure 3.3. The HPW (room 121) is protected for a flood height of 13.25 m +NAP due to the height of the inlet of the passive air cooling, indicated at the right part of Figure 3.3. The control room is located at a height of 15.27 m +NAP, the floor of the emergency power equipment at a height of 10.47 m + NAP (not indicated inFigure 3.3).

In Figure 1.8, Figure 1.9 and Figure 1.10 cross-sections of the HABOG building are given showing the processing of respectively RR-HPW, V-HPW and non-HPW. In step 2 and 3 of the RR-HPW process the waste is unloaded and repacked. In step 3 and 4 of the V-HPW and non-HPW process the transport container is unloaded. The rooms in the mentioned steps are provided with redundant drives (e.g. for hoisting equipment) and emergency equipment to store waste (including unfinished repacked waste) in safe and shielded positions in case of failures or power outages, caused by malfunctioning or internal/external events (for instance the consequences of flooding).

As a preventive measure (not formalized in procedures), unloading and repackaging activities can be cancelled/finished when weather forecast predicts threatening conditions to the site. The HABOG organization is informed by the SVSD service when these conditions may occur. The SVSD service (stormvloedwaarschuwingen kust en benedenrivieren) is a cooperation between the department water management of the Ministry of Infrastructure and Environment (Rijkswaterstaat) and the Royal Dutch Meteorological Institute (KNMI). In general, there will be enough time to finish all activities and have the waste stored in the cylindrical containers (HPW, step 5 Figure 1.8 and Figure 1.9) and the storage compartment (non-HPW, step 5 Figure 1.10).

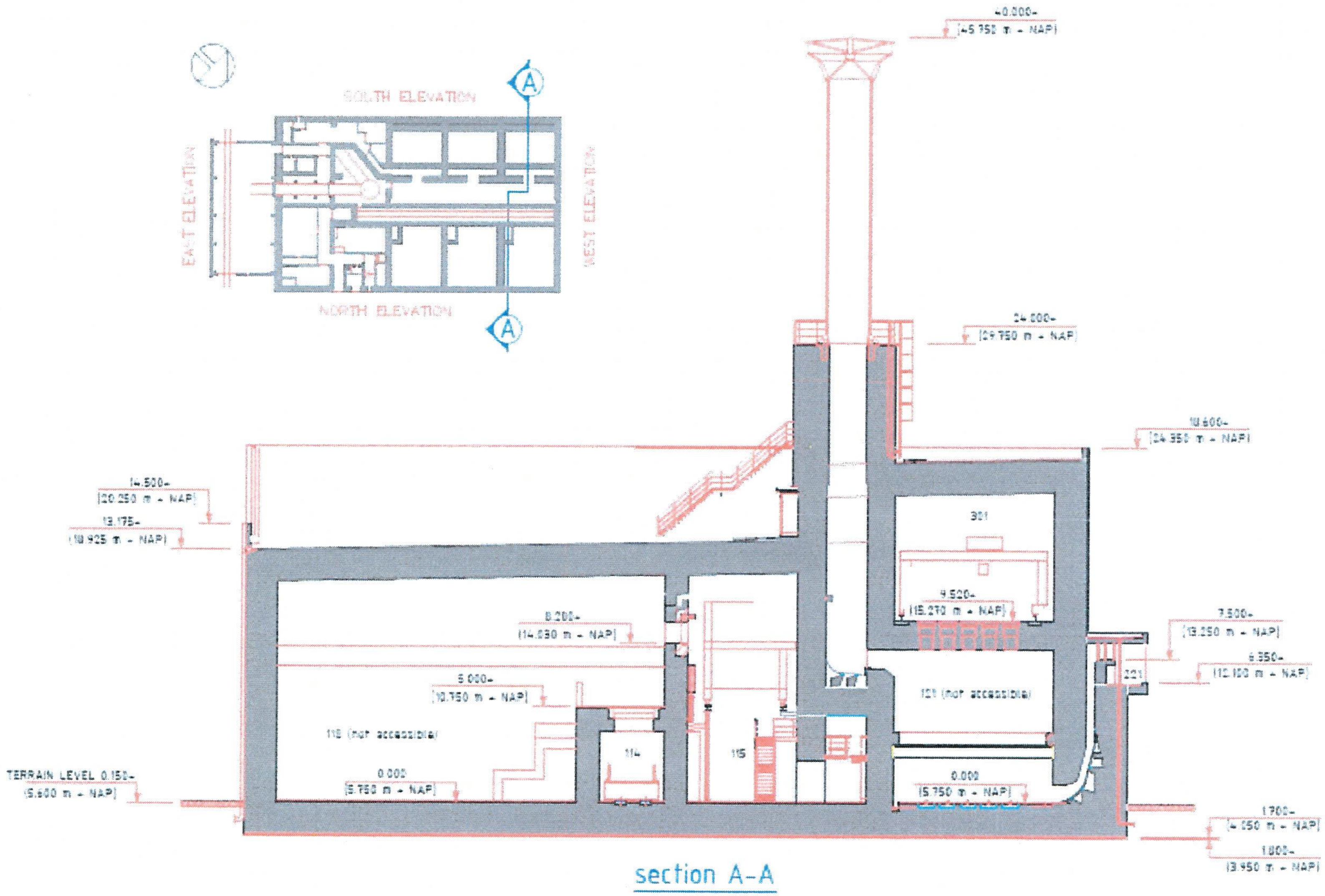


Figure 3.3 Level indications of the HABOG building (cross section). Room 118 contains the non-HPW, room 121 the HPW.

3.1.3 Plant compliance with its current licensing basis

HABOG has its own maintenance system and operating procedures to ascertain the proper functioning of structures, systems, and components. No specific measures and procedures exist for external flood situations (i.e. not for design basis flood as well as beyond design basis flood).

As there are no procedures and processes to deal with flooding situations, there are no procedures that deal with mobile equipment and other supplies. Due to the design of the HABOG building, its facilities and its passive safety features, mobile equipment and other supplies are deemed not necessary.

3.2 Evaluation of safety margins

3.2.1 Estimation of safety margin against flooding

In section 3.1.1 it is evaluated that a flooding above NOP is very unlikely to occur. However, for the evaluation of safety margins in this section severe flooding is postulated.

The three fundamental safety functions are evaluated for flood levels beyond NOP. At this water level the building will be flooded. The water enters the building via openings in the building e.g. from doors and it is assumed that it will spread out in the rest of the building. Water also enters the air inlet. The (ultimate) consequences of water entering the HABOG building are described below.

Failure of electricity supply

For this flood level failure of the (emergency) electricity supply is assumed. When normal electricity supply fails, essential electricity users like monitoring and control equipment are automatically fed by emergency power, equipped with static no-break sets (see section 5). When emergency power fails, all support systems fail. For the fundamental safety functions this means the following:

- Confinement of the waste. The confinement of the waste is not influenced by electricity. As a result of loss of emergency power, the ventilation system fails and very small amounts of radioactive materials (like noble gases) could spread over the building. Due to failure of monitoring equipment it is not possible to have actual data about radiation levels in the compartments or support rooms.
- Cooling of the waste. The passive cooling system is not influenced by electricity supply.

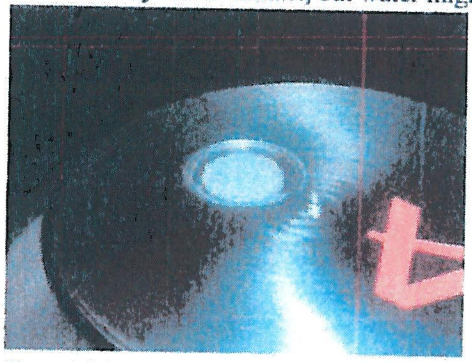
- Criticality safety. Failure of electricity supply does not influence sub-criticality in any possible situation in HABOG.

Flooding of the compartments

It is assumed that the water will flood the storage compartments and the repackaging room. For the fundamental safety functions this means the following:

- Confinement of the waste. The waste is separated from the environment by several, waterproof, layers. For the HPW the barriers are the immobilized waste (the glass matrix and fuel matrix), a canister in which the immobilized waste is placed and the cylindrical wells in which the canisters are placed.

  For non-HPW, the canisters are stored in the storage room. The integrity of the canisters is not threatened by water contact, but water might penetrate into the narrow Poral filters (filter performance: 99.9% filtration of particle sizes down to 4.5 μm for liquid and 0.5 μm for gas) in the cover of the canister as presented in Figure 3.4. Although it is very unlikely that large amounts of water will penetrate into the canisters, within the scope of this it is assumed that the canisters will be filled with water. When the external flood level decreases below NOP, the water (in potential not or very less contaminated or activated) can be pumped out of the storage room. Due to the heavy weight and positioning of the canisters, it is not expected that canisters have been tilted during flooding conditions. The canisters, assumed to be filled with water and non-HPW, do not form a potential threat to the environment. When returned to normal external conditions there will be enough time for evaluation of the assumed situation of the waste storage. In principal, the water in the canister will evaporate and escape via the Poral filters. The same applies for formed gases (e.g. as a result of radiolysis).

  
  Figure 3.4 Poral filter in the cover of a canister

  Due to the weather forecasts much time is available before significant flooding occurs at the site, therefore it is not expected that transport containers will be present in the reception area during this event. Transport containers are leak tight according to the requirements of the ADR and IAEA TS-R-1.

- Cooling will take place by the entered water in the storage vault. The heat capacity of water is much larger than of air and temperature rise of the cooling water in the vault will be very slow due to the

large water mount. The water transfers the absorbed heat to the environment by evaporation and heat exchange with the walls.

- Criticality safety has been investigated for inundation of the compartments, wells and canisters (referring to accident conditions, the cylindrical wells and canisters are gas- and waterproof). For the wells and canisters, respectively Argon and Helium gasses are replaced by water. Water is an effective moderator, so criticality can increase when air, Argon or Helium are replaced by water. Calculations by ECN/NRG showed criticality safety under these conditions using conservative parameter assumptions and waste type combinations.

In the above a qualitative description is given concerning the fundamental safety functions when the flood has reached above the design level. Due to the fact that no (significant) radioactive releases occur within these conditions, further safety margins are not relevant for this event, which leads to the conclusion that extreme flooding does not lead to cliff-edge effects.

3.2.2 Measures which can be envisaged to increase robustness of the plant against flooding.

The preventive measures which may be necessary in case of potential threatening weather conditions can be formalised in procedures.

4 Extreme weather conditions

4.1 Design basis

This chapter describes the design basis of HABOG with respect to extreme weather conditions. The following weather conditions are taken into account:

- extreme high and low air temperatures
- extremely high wind (including storm and tornado)
- wind missiles and hail
- heavy rainfall
- heavy snowfall
- formation of ice
- lightning
- credible combinations of the conditions mentioned above.

4.1.1 Reassessment of weather conditions used as design basis

The data on extreme weather conditions is collected at the KNMI weather station at Vlissingen [7]. The data is collected between 1906 and the present.

Extreme high and low air temperatures

The maximum air temperature measured is 35.5 °C on 19-07-2006. According to the Intergovernmental Panel on Climate Change (IPCC) a temperature increase of 1.1 to 6.4 degree for the next century is probable [8].

The maximum allowable temperatures for the radioactive waste are shown in Table 1.1 for normal operating conditions and Table 1.2 for accidental conditions. The design of the passive ventilation cooling is such that high air temperatures are no threat for the heat removal (i.e. no exceeding of limit temperatures). Conservative values are used in the design. In Table 1.3 an intake air temperature of 27°C is used, which is much higher than the outside temperature in winter periods and on average higher in summer periods. Due to the very high heat capacity of the HPW, the temperature of the HPW is fairly

independent of outside temperatures. No adverse consequences will result from possible high air temperatures for the safety functions of HABOG.

The lowest air temperature measured is -10.4 °C on 20-12-1938. At extremely low outside air temperatures the following effects must be avoided:

- decrease in the quality of the diesel fuel inventory
- freezing of coolant for the diesel generators
- freezing of the fire extinguishing water inventory.

All rooms in HABOG are heated and the waterlines are underground, so freezing effects will not occur for these systems. The heat removal of HABOG is not threatened by very low temperatures (e.g. by freezing phenomena etc.). In general, for systems related to safety functions, sufficient resistance against low temperatures is guaranteed by design.

Extremely high wind (including storm and tornado)

For HABOG a whirlwind with a wind velocity of 125 m/s maximum is considered as the design base.

For wind types, the following subdivision is used:

- Extreme wind speed (hourly average)
- Wind gusts (usually less than 20 seconds)
- Whirlwinds (unpredictable).

<u>Extreme wind speed</u>

The highest wind speed measured is 29.8 m/s on 02-01-1976 (Vlissingen). Research shows that the maximum wind speed (hourly average) that can be expected once every 10,000 years is approximately 35 m/s [9].

<u>Wind gust</u>

A wind gust is a sudden, brief increase in speed of the wind. The duration of a gust is usually less than 20 seconds. KNMI has determined that the maximum wind gust is roughly 1.5 times the maximum hourly average wind speed [10]. At a wind speed of 35 m/s, this results in a maximum wind gust of 53 m/s once every 10,000 years on average. The highest wind gust measured is 41.2 m/s on 25-01-1990.

Whirlwind

The highest wind speed that was observed by a monitoring station due to a whirlwind in the Netherlands is 56 m/s. On average, each year about two whirlwinds cause some damage to the infrastructure somewhere in the Netherlands, over an area of one square kilometre. It is estimated that for a random location in the Netherlands, the risk of damage by a whirlwind is 10^{-5} per year [10].

For further evaluation of the structural building integrity, an maximum expected wind speed of 56 m/s is adopted to evaluate the design basis. For the design basis, a wind velocity of 125 m/s (estimated frequency of occurrence: 10^{-6} per year) is adopted.

Consequences

The design basis wind velocity is 125 m/s, which gives a significant safety margin to the maximum highest wind velocity that was monitored in the Netherlands (56 m/s).

Damage to the steel and concrete construction of the building, with exception of the stack, is not credible. The stack has a breaking point which, in case of a break, results in an acceptable stack height regarding the passive cooling system.

Wind missiles and hail

Wind missiles are projectiles propelled by extreme wind. A credible effect caused by projectiles could be loss of offsite power due to damage to the power lines or the switchyard. This type of event is included in the loss of offsite power sequences (see Chapter 5).

Wind turbines

Two wind turbines are located in the vicinity of the COVRA site (indicated with red circles in Figure 4.1). Due to high wind velocities blades can tear off and be like missiles. From a risk evaluation by TNO it turned out that only the AVG and LOG could be hit by a broken wind turbine blade. As a consequence, the wind turbines are no threat for the fundamental safety functions of HABOG.

Figure 4.1 Location of the windturbines (indicated with red circles)

Other effects that may be caused by wind missiles will be less than the impact of an design basis airplane crash and have therefore no impact on nuclear safety.

Hail is defined as precipitation in the form of spherical or irregular pellets of ice larger than 5 mm in diameter. Depending on the size of the pellets, some damage to objects can be expected. It is concluded that hail has no impact on plant safety.

Heavy rainfall

Extreme rainfall may induce additional force on building roofs. Because of raised edges water can accumulate on top of the buildings if all drainage pipes are blocked. The largest recorded amount of rainfall in one hour in Vlissingen is 36.9 mm on 23-07-1971. The largest amount of rainfall in one day is 80.9 mm on 04-07-2005.

The statistics of the KNMI show that for the area of Vlissingen once every thousand years (10^{-3} per year) 108 mm of rainfall can be expected within a period of 24 hours [11]. For the same conditions, 123 mm of rainfall can be expected within 48 hours. The roof of HABOG has a thickness of 1.7m and is designed for an airplane crash. HABOG is strong enough to withstand the credible consequences of rainfall.

Extreme rainfall may also lead to flooding. This topic is covered in chapter 3.

Heavy snowfall

Heavy snowfall may lead to accumulation of snow on roofs, inducing a load on the civil structure. HABOG is designed to withstand the credible consequences of snowfall. Building standard NEN 6702 specifies a maximum snow load on flat roof tops of 0.56 kN/m^2; which corresponds to a level of fresh snow of approximately 0.56 m.

On average, occasions of more than 20 cm of snowfall occur once every 10 years and more than 35 cm occurs once every 50 years [12]. However, if it continues to snow for an extended period, larger values of snow build up can be expected. Also, if snow thickens due to alternating high and low temperatures, density may increase. Since the design load of the roof of HABOG is much higher than the maximum load according to NEN 6702, due to the heavy reinforced concrete structure, a significant safety margin is available. A conservative estimation of the maximum snow load, by taking a snow mass corresponding to about 10% weight of the roof, results in a snow height of more than 4 meter.

Formation of ice

The formation of ice on the Westerschelde does not influence the safe operation of HABOG, because HABOG activities, building and surrounding area are independent of the Westerschelde, and HABOG is at sufficient distance from the Westerschelde.

Lightning

Lightning occurs on average 2 to 3 times per km^2/year. Lightning strikes occur in the region of COVRA approximately 24-26 days a year [13]. Lightning has never been an issue for the safety of HABOG. HABOG is equipped with lightning protection, which is connected to the grounding points. The lighting protection is according to the NEN-norm 1014 ('Bliksembeveiliging'). Lightning strike may have an impact on electrical systems such as the instrumentation and controls of HABOG, but this will not have an impact on nuclear safety.

Credible combinations of the conditions mentioned above

1. Snow + extreme wind,

2. Extreme wind + extreme rainfall + lightning.

Ad 1. Snow and wind combined may lead to formation of ice in the air inlet of HABOG. This may block the air inlet and thereby the cooling of HABOG. However even in the case of a full blockade of the air inlet, temperatures stay below limit temperatures for normal operating conditions (Table 1.1) for a long time

(several months, estimation based on KEMA calculations). The few months give enough time for accident management measures for de-icing the air inlet, which makes the risk for a blocked air inlet due to snow and wind negligible.

Ad 2. High winds, combined with extreme rainfall and lightning can be expected during a thunderstorm. Because the loads caused by these weather conditions are different, they will not reinforce each other's effect on the plant.

Conclusion on the adequacy of protection against extreme weather conditions

The separate phenomena are discussed in paragraph 4.1.1. It can be concluded that no serious consequences are to be expected from these phenomena.

4.2 Evaluation of safety margins

4.2.1 Estimation of safety margin against extreme weather conditions

This paragraph contains an analysis of the potential impact of different extreme weather conditions on the safe operation of HABOG. The safety margin is defined as the difference between the allowable load (by design and/or by building standard) and the maximum load on buildings that can be expected as a result of the extreme weather conditions. Loads due to snowfall, rainfall and wind are derived from the weather conditions listed in the previous section. The remaining conditions (air temperature, formation of ice and lightning strike) cannot be translated into explicit loads on buildings and are only qualitatively discussed (i.e. not quantified).

Extreme high and low air temperatures

Extreme high outside air temperatures will not threaten the fundamental safety functions of HABOG. The heat removal of HABOG is well overdesigned to deal with extreme high outside temperatures. For exceeding the limit temperature for normal operating conditions, the temperature in the centre of the V-HPW must be over 500°C (Table 1.1). For normal conditions the maximum temperature in the centre of the V-HPW is about 460°C (Table 1.3). This temperature difference gives sufficient safety margin with respect to the highest outside air temperature.

Extreme low air temperatures will not have an effect on the systems which are essential for confinement and prevention of criticality. Low temperatures may have an impact on the diesel generators, but these are

located inside the building and therefore not exposed to these low temperatures. In addition, the diesel generators are not needed for maintaining the fundamental safety functions (see chapter 5).

Extremely high wind (including storm and tornado)

The maximum wind speed (56 m/s) is significantly lower than the design basis (125 m/s) of HABOG. No cliff-edge is expected concerning the failure of the buildings due to either maximum credible wind gusts or whirlwinds.

Wind missiles and hail

No cliff-edge is expected concerning the failure of the buildings due to either wind missiles or hail. No quantifiable margin for wind missiles and hail can be given.

Heavy rainfall

Even in the incredible case that water is accumulated on the roof the load will not be higher than the maximum load. This gives considerable margin concerning heavy rain fall.

Heavy snowfall

In the case that snow is accumulated on the roof the load will be lower than the maximum load. The safety margin is at least 4 meter.

Formation of ice

Formation of ice on the Westerschelde is not relevant for HABOG. No quantifiable margin for ice formation can be given.

Lightning

If the facility is subjected to lightning pulses with amplitudes above the designed levels, damage or spurious actuation of instrumentation and controls may be initiated. In an unlikely case this might lead to the shutdown of several systems or a situation of loss of off-site power (see chapter 5), but not resulting in off-site consequences.

4.2.2 Measures which can be envisaged to increase robustness of the plant against extreme weather conditions

No measures are deemed necessary to increase the robustness of the plant against extreme weather conditions.

5 Loss of electrical power and loss of ultimate heat sink

5.1 Loss of power

The power supply of HABOG is described in section 1.3.4. The power supply system is important for HABOG operations but provides no support to nuclear safety functions. All systems required for supporting the safety functions have a passive safety design. All other processes are designed to shut down in a safe manner following loss of power.

Consequences

On failure of external power supply, essential electricity users necessary for bringing the facility in a safe (in terms of working conditions) and manageable condition, are connected to the emergency power supply. This refers e.g. to the ventilation and hoisting facilities of the unloading and packaging room, the (monitoring and registration) instrumentation and emergency lighting. The hoisting equipment has a failsafe response to failure of the power supply. After connection to the emergency power the operations with the waste can safely be resumed and terminated.

The essential electricity users are connected to the uninterrupted power supply (UPS) and a (one) diesel generator. The diesel generator will start automatically when loss of external power supply occurs. The UPS battery has a capacity of 5 hour (in 2002 increased from 30 minutes to 5 hour) for feeding control, monitoring and safeguard equipment. The diesel generator is located at the first floor (+10.51 NAP). The diesel stock tank on the first floor (separated from the generator room) has a capacity for about one day. Extra diesel can be brought in via a pipe connection in the reception area. Outside the building, directly beside the reception area entrance, there is a connection point for a mobile power generator (see Figure 5.1).

Figure 5.1 Connection point for mobile power generator

Components that are powerless after loss of external power supply, like the crane in the reception area, can be supplied with emergency power after procedural handling and release by the control room.

If emergency power is not available (station blackout, no diesel generators and UPS), the loss of the forced ventilation system does not lead to the release of radioactive products or the increase of temperatures above the limit values. The consequences and possible actions for the loss of forced ventilation are described below for the different rooms/areas (not taken in procedures):

- Reception area: heat from the waste can be removed by walls, roof and doors. The temperature of the area increases slowly. If necessary, entrance doors can be opened to remove the heat
- Preparation room: heat from the waste can be removed by walls, roof and doors. The temperature of the area increases slowly. If necessary, the cover, still on the container, can be screwed on the container and the container can be transported to the reception area
- Packaging room (hot cell): heat can be removed by walls, floors and doors. If necessary, for instance during overpacking of a V-canister, the transport opening to the unloading room can be opened
- Unloading room: in the situation with an open (cover removed) transport container filled with vitrified material, an equilibrium temperature of 430° C of the V-HPW will be established after several months. The limit temperature for normal operating conditions is thereby not exceeded.
- Storage room non-HPW: the very small release of hydrogen gas from the non-HPW is transported directly to the stack. When hydrogen is not removed from the storage room (e.g. due to blockage of the stack), it will take years to build op a hydrogen concentration in the storage rooms which exceeds the allowable limit (about 4%).

In a situation of station black out, monitoring and registration instruments stop functioning, so the actual status with concern to radiation levels and releases are not known in the different areas and compartments. For alternative monitoring actions, portable monitors from the HABOG control room or the AVG building (reception room) can be used.

5.2 Loss of ultimate heat sink

In section 1.3.2 the cooling system of HABOG is described. The cooling system consists of a natural convection system for the cooling of the heat producing waste. Cooling is required for the long term, to maintain the storage of the heat producing waste within the safety boundaries, i.e. below the limit temperatures (shown in Table 1.1 for normal operating conditions and Table 1.2 for accidental conditions).

The natural convection system is designed in such a way that the maximum allowable temperatures of the heat producing waste and construction materials are not exceeded during normal operation, malfunctions or accidents (e.g. break of the stack).

Calculations show that even with a 95% blockade of the air inlet the maximum temperature for accident conditions of the V-HPW is not exceeded (calculated by KEMA). Even in the case of a full blockade of the air inlet, temperatures stay below limit temperatures for normal operating conditions for a long time (several months, estimation based on KEMA calculations). The situation of a fully blocked air inlet for a long period can be considered as highly unrealistic.

5.3 Loss of ultimate heat sink combined with station blackout

Cooling of the waste is independent from any power source. The consequences of loss of ultimate heat sink and station blackout (no AC-power at all) are described in the former sections.

5.4 Evaluation of safety margins

Loss of ultimate heat sink in combination with station blackout does not threaten the fundamental safety functions control of reactivity and confinement of radioactivity. Cooling of the waste is only threatened, i.e. leading to exceedance of limit temperatures for normal conditions, when the air inlet is fully blocked for a very long period (several months). Full blockage of the air inlet for such a long period is considered as highly unrealistic. The safety margin is therefore very high.

Exceedance of the limit temperatures (for normal operation) for a long time can result in partial crystallisation of the glass matrix and may have impact on material properties, like from the canisters, wells and concrete (confinement). The confinement function is not threatened in this situation. However, due to the impact on material properties it is possible that design requirements with respect to confinement functions may not be met in the future.

5.5 Conclusions

Loss of ultimate heat sink in combination with station blackout does not threaten the fundamental safety functions. Cooling of the waste is only threatened, i.e. leading to exceedance of limit temperatures, when

the air inlet is fully blocked for a very long period. Full blockage of the air inlet for such a long period is considered as highly unrealistic. The safety margin is therefore large.

5.6 Measures which can be envisaged to increase robustness of the plant

One measure is identified to increase the robustness of the plant:

- Formalise measures in case of loss of power (station black out).

6 Other extreme hazards

The following extreme events were identified for this analysis:

- explosion and fire related hazards:
  - internal explosion
  - external explosion
  - internal fire
  - external fire
  - airplane crash
  - toxic gases
- electrical related issues:
  - large grid disturbance
  - failure of systems by introducing computer malware
- water related issues:
  - internal flooding.

The following information is elaborated for each of these hazards:

- General description of the event
- Description of how the event could lead to consequences for the safety systems
- Elaboration on these consequences.

6.1 Internal explosion

Internal explosions are defined as being those explosions that originate from plant systems and plant storages. To protect SSCs against the impact of internal explosions the number and volume of explosive materials is reduced and risk areas are ventilated.

The risk of an internal explosion at HABOG can be described by the following scenarios:

- Explosion of diesel inventory
- Hydrogen explosion.

The diesel room area is a classified fire compartment. For this area, an automatic extinguishing system (a fine water spray system which is fed by the UPS) is implemented. This system starts (and stops) automatically in case of fire but can be operated manually also. It is also possible to use the available manual foam/CO_2 fire extinguisher. In the diesel room the tank has a capacity of only one day of generator operation. Due to the small amount of diesel, the classified fire compartment and the extinguishing systems the fire will be limited and will not be a threat to the fundamental safety functions.

The hydrogen explosion hazard results from the radiolysis hydrogen released by the non-HPW. Together with oxygen, hydrogen can form an explosive atmosphere. The flammability lower limit of hydrogen in air is 4 %. However the hydrogen flow is very low in relation to the bunker volume. The time before reaching 4 % H_2 in the bunker (without any ventilation) is about 425 days. According to analysis of SGN, it was concluded that there is no risk of a hydrogen concentration higher than 4 % since dilution by the building ventilation system is ensured regularly. The design is such that any dead zone that can not be ventilated is avoided.

6.2 External explosion

Explosion pressure waves can generally result from accidents in nearby facilities or means of transportation. The potential damage can result from pressure wave impact. Risk evaluation by COVRA shows that the maximum overpressure resulting from any pressure wave at the COVRA site is 0.14 bar. The design basis is NVR 3.1, which assumes a maximum overpressure wave of 0.3 bar.

The potential sources of shock waves are shown in the risk map of the area around HABOG in Figure 6.1.

The risk map shows the risks of death for people (10^{-6} /y), the risk of damage to HABOG is much lower. HABOG is located in the centre of the map. This risk map shows that external explosions may originate from:

- The main gas pipeline (south and east)
- Nuclear power plant Borssele (south)
- Heerema Marine Contractors (north–west)
- Transport via the rail, the road Europaweg-zuid (south-east), river Westerschelde (south) and the harbour
- Winturbines
- Zeeland Refinerty (north-east).

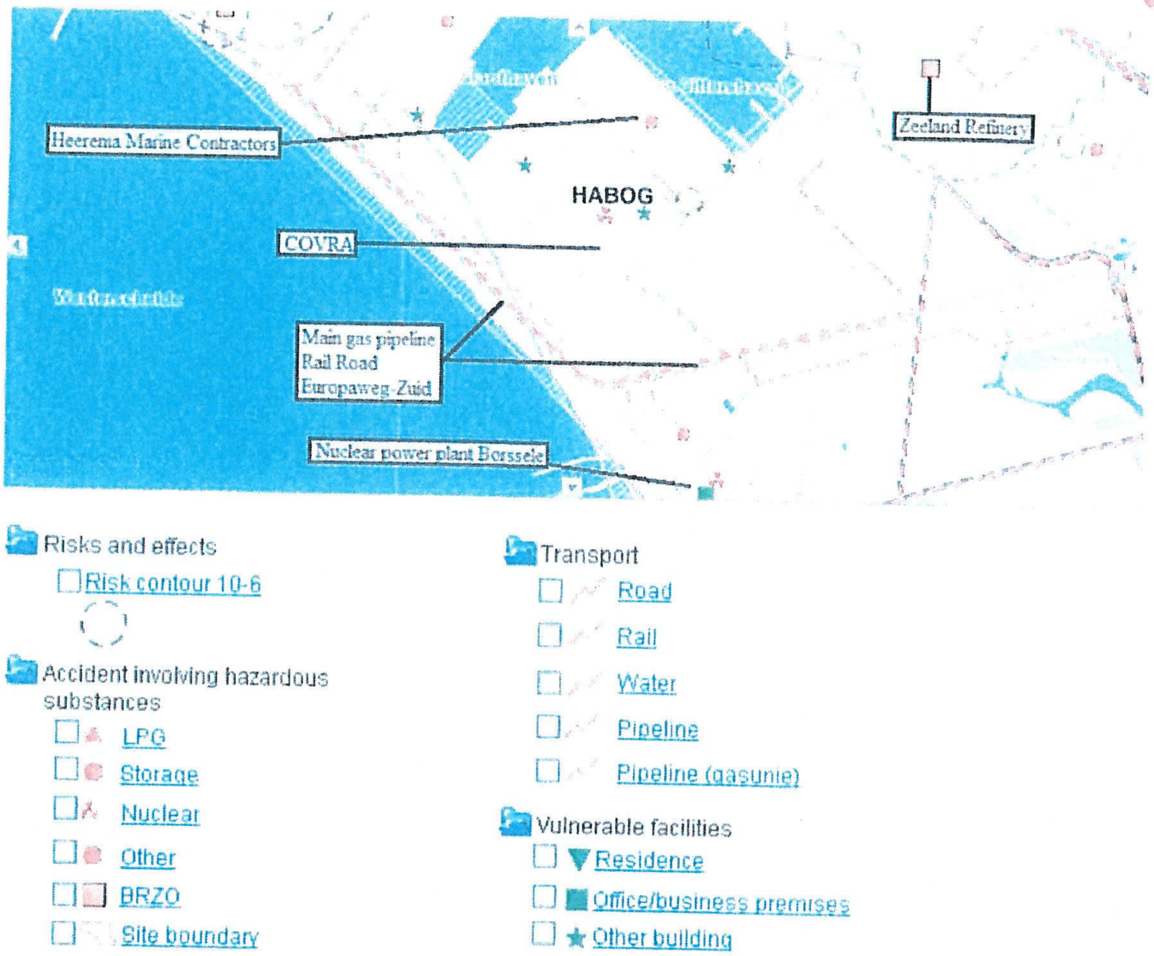


Figure 6.1 Risk map of the area around HABOG and legend [14]

There is no serious threat from explosions/fires from buildings at the COVRA site. The COVRA site does not have a 10^{-6} risk contour.

6.2.1 Main gas pipeline

The distance of HABOG to the main gas pipeline is approximately 400m. The legal standard for high pressure gas pipelines is a 10^{-6} risk contour which is 5 meters from the pipeline. For this specific pipeline the 10^{-6} risk contour is even smaller (0 m) [14]. Because of the distance to the pipeline, the shockwave due to an explosion of the main gas pipeline will be strongly decreased when it reaches HABOG. The risk for a threat of the fundamental safety functions due to an external explosion will therefore be negligible.

6.2.2 Nuclear power plant Borssele

The risk contour of the nuclear power plant Borssele is not shown on the risk map of Figure 6.1. The risk contour with a risk of death of 10^{-6}/y falls within the site boundaries of EPZ [6]. This risk is however not related to an external explosion but to radiological incidents. The risk contour of any possible explosion falls well within the site boundary. The risk for a threat of the fundamental safety functions due to an external explosion will therefore be negligible. A radiological incident can have the same type of effect on HABOG as toxic gases, which are described in section 6.6.

6.2.3 Heerema Marine Contractors

Heerema Marine Contractors (HMC) is a marine contractor in the international offshore oil and gas industry. The black dashed circle at the south of the Heerema site indicates a risk contour with a risk of death of 10^{-6}/yr. There is a risk contour over the terrain of COVRA from Heerema where due to the use of hazardous substances. At the Heerema site there is an aboveground storage tank with 18 m^3 of liquid gas. The risk contour runs on the part of the COVRA site where no building stands, but only one pond.

Because of the distance from HABOG to the storage tank and the relatively small amount of liquid gas, the shockwave due to an explosion of the storage tank will be strongly decreased when it reaches HABOG. The risk for a threat of the fundamental safety functions due to an external explosion will therefore be negligible.

6.2.4 Transport via rail, road, river and harbour

External explosion

At the industrial area gasses and liquid fuels are transported via rail, road (Europaweg-zuid) and river (Westerschelde). A gas or fuel explosion caused by an accident with a fuel train, truck or ship, may occur locally. The distance from the main road, rail, surrounding harbour and the main shipping route to HABOG is respectively 500m, 500m, 500m and 2000m. Because of this distance the shockwave due to an explosion will be strongly decreased when it reaches HABOG. Damage, directly or indirectly, to the fundamental safety functions of HABOG due to an external explosion on the rail, the road, the harbour or the river will therefore be negligible.

Gas cloud explosion

A study of TNO concluded that a flammable gas cloud at the COVRA site could only be caused by accidents with large ships carrying liquid natural gas on the Westerschelde. Calculations show that the concentrations of the gas at the COVRA site that exceed the lower explosion limit cannot be excluded. This means the gas could be detonated onsite or even inside HABOG. The overpressure inside the rooms due to the internal explosion has been calculated by TNO. Without performing structural analysis, it has been judged that these high overpressures may lead to structural damage and that preventive measures should be taken to avoid an internal explosion.

To prevent a gas cloud explosion inside HABOG, electrical igniters (Figure 6.2) are placed outside of HABOG at carefully chosen positions in the air inlet. Due to the availability of an emergency diesel generator the operability of the electrical igniters is guaranteed in the case of a loss of power. Therefore the risk for a gas cloud explosion will be negligible.

The risk of transport of toxic gasses via the Westerschelde is discussed seperately in paragraph 6.6

Figure 6.2 Part of the gas detection system

6.2.5 Zeeland Refinery

At the Zeeland Refinery crude oil is refined to several fuels and oils. The Zeeland Refinery is part of the BRZO (Besluit Risico's Zware Ongevallen) of the Dutch authorities. The BRZO contains additional safety regulations especially for high-risk companies.

The black dashed line around the Zeeland Refinery (Figure 6.1) indicates the risk contour with a risk of death of 10^{-6}/yr. This risk contour is at a significant distance (>1km) form HABOG. The Zeeland Refinery is located at a distance of approximately 1 km from HABOG. The risk for a threat of the fundamental safety functions due to an external explosion will therefore be negligible.

6.3 Internal fire

The risk of an internal fire inside the storage areas is very small due to the very low amount of combustible inventory in HABOG. The areas where more combustible material is present are accommodated with fire detection systems. The system gives sound and visual alarms in the control rooms of HABOG when detecting a fire.

In the areas where mechanical processes are implemented (like cranes and transportation vehicles) and where there is a concentration of cables or electrical equipment (motors, switchgears, cabinets), the postulated source of fire is electrical. All areas containing a fire load density higher than 400 MJ/m^2 are classified fire compartments.

Fire compartments are separated from surrounding areas by fire stop barriers (integrated in walls, ceiling, floor, doors, air inlet and exhaust dampers, wall crossings). Resistance requirement for fire stop barriers is 90 minutes at least. Fire detection systems are systematically provided in these areas. Portable extinguishers located at the entrance of the areas facilitate quick extinguishing of any fire.

In case of fire due to process equipment in the working areas, personnel can use suitable portable or mobile extinguisher, which are present in all the areas. The diesel room is equipped with an automatic extinguishing system (fine water spray system).

The risk of a fire in the storage area is small and the risk of a release of large amounts of radioactive material in the case of a fire is extremely small.

6.4 External fire

The risks of the surrounding area are shown in the risk map of the area around HABOG in Figure 6.1 in section 6.2. The risk of an external fire results from:

- The main gas pipeline (south-east)
- Heerema Marine Contractors (north-west)

- Transport via the rail road (south-east)
- Transport via the road Europaweg-zuid (south-east)
- Coal Storage (south).

Fire at ships carrying (liquid) fuels on the Westerschelde are not a threat for HABOG because of the natural shielding of the water which prevents spreading of the fire. A kerosene fire due to airplane crash is addressed in section 6.5.

A major influence on the spreading of an external fire is the wind direction. The wind rose of Figure 6.3 shows that the main wind direction is south-west. The highest chance of fire is therefore from the coal storage.

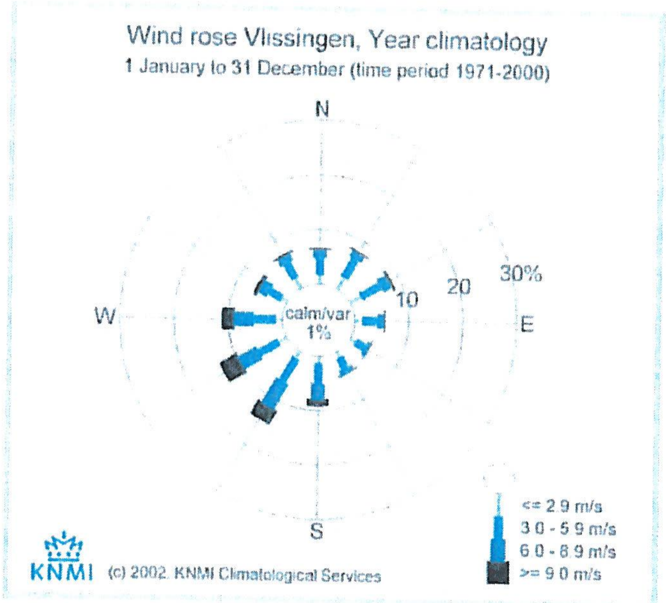


Figure 6.3 Wind rose, measured at KNMI station Vlissingen

6.4.1 Main gas pipeline

The distance to the main gas pipeline is approximately 400m. The area between HABOG and the main gas pipeline consist mainly of grassland. The fire load is so low that spreading of the fire from the main gas pipeline to HABOG through this way is not possible.

NRG

6.4.2 Heerema

At the Heerema site there is an aboveground storage tank with 18 m^3 of liquid gas. In Figure 6.1 the 10^{-6}/y risk contour is shown, which covers a small part of the COVRA terrain where no buildings are located. The area in between is covered with a road, short grass and a pond, which makes the possibility of transportation via the ground negligible.

Spreading of fire to HABOG by external fire at the Heerema site is possible, however only by indirect means (delivery of sparks). HABOG is mainly made of steel and concrete and therefor has a low probability of catching fire. Also the wind rose of Figure 6.3 shows that the chance of wind directly from the Heerema site to HABOG is small.

Due to the short distance of the Heerema site to the COVRA site the influence of smoke and heat production should be considered. Both heat and smoke will have influence on the ventilation system of the COVRA facilities. Smoke and heat will not have (a threatening) influence on the fundamental safety functions, but will influence the safety of personnel at the COVRA site. Evacuation of personnel at the COVRA site due to fire at the Heerema site will however not cause any safety concerns.

6.4.3 Transport by road and rail

Transport of liquefied gasses takes place via the rail and the road Europaweg-zuid. The distance from the road and the rail to HABOG is approximately 500m. The area between HABOG and the road and the rail consists mainly of grasses. The fire load of the grasses is so low that a spreading of the fire from the road and the rail to HABOG through this way is not possible.

6.4.4 Coal storage

A coal storage of EPZ is located 300m to the south-west of HABOG (see Figure 6.4). The coal storage from EPZ can contain a maximum of 300,000 ton coal [16].

Figure 6.4 Location of the coal storage

Figure 6.4 shows that the area in between HABOG and the coal storage is covered with short grass which makes the possibility of transportation via the ground negligible. Ignition of HABOG by external fire at the coal storage site is possible, however only by indirect means (delivery of sparks). HABOG is mainly made of steel and concrete and therefor has a low probability of catching fire.

The wind rose of Figure 6.3 shows that the main wind direction is from the coal storage to HABOG. In the case of a fire of the coal storage the influence of smoke and heat production should be considered. Both heat and smoke will have influence on the ventilation system of the COVRA facilities. Due to the limited time that a coal fire will exist (after a few days it can be assumed that the fire will be extinguished) and the time necessary to reach limit temperatures of the HPW (e.g. in the case of a fully blocked inlet this will be several months) the smoke and heat will not have (a threatening) influence on the fundamental safety functions. It will influence the safety of personnel at the COVRA site. Evacuation of personnel at the COVRA site due to fire at the coal storage will however not cause any safety concerns.

6.5 Airplane crash

HABOG is located in the general fly zone of the civilian air traffic. The airport Zeeland in Arnemuiden, which is used for small aircrafts only, is located 10 km to the north of the HABOG. The nearest larger civilian airports (for airplanes weight larger than 5700 kg) are Rotterdam airport (Zestienhoven) and Brussel airport (Zaventem) at a distance of respectively 75 and 80 km. The nearest military airport is

located in Woensdrecht, which is approximately 40 km from the HABOG. HABOG is designed for an airplane crash of a F-16.

In order to analyze the effect of a beyond design base accident the Nationaal Lucht- en Ruimtevaartlaboratorium (NLR) has calculated the chance of a military airplane crash on HABOG. The Hollandsche Beton en Waterbouw BV (HBM-HBW) has analyzed the consequences of a beyond design base airplane crash on HABOG. The main conclusions are:

- When the impact angle is smaller than 45° (90° is perpendicular), no perforation of the wall or roof surface will occur. The wall or roof surface will maximally 1 meter be pressed inwards. No ruptures are created where radioactive material could be released from the containment.
- If the impact angle is between 45° and 90° degree, the wall or roof surface may (depending on the geometry) collapse.

Based on the findings of the Hollandsche Beton en Waterbouw BV a source term is defined for beyond design base airplane crash. The assumption is made that a certain percentage of the radioactive waste that is stored near the damaged wall, is released. The effects of a kerosene fire are judged to be small and are neglected; it is assumed that the fire lasts very short and takes place outside the HABOG building. The Nuclear Research and consultancy Group (NRG) determined the consequences for the residents near HABOG, presented in the (new, draft) Safety Report. It was found that the individual risk at the site border (100 meter from the release point) is $1.6\ 10^{-10}$ per year for adults and $5.9\ 10^{-10}$ per year for children. These values are far below the limits.

6.6 Toxic gases

In this chapter the risks of the release of toxic gasses are discussed. The risk of the release of toxic gases originates from:

- the COVRA site
- the surrounding companies
- rail and road transport
- a ship on the westerschelde.

In all the cases the toxic gasses may affect the personnel at HABOG. HABOG does not need control from the control room to assure the fundamental safety functions. Therefore, unavailability of (control room) staff/personnel does not threaten any of HABOG's fundamental safety functions.

The explosion of the toxic gasses is covered in chapter 6.2.

In case of release of radioactive material from KCB, fundamental safety functions of HABOG are not threatened. No measures are defined for this situation.

Recommendation: Extend the emergency plan of COVRA (BNP) with measures concerning significant radioactive releases of the adjacent NPP KCB.

6.7 Large grid disturbance

The power supply system is important for HABOG operations, but provides no support to the fundamental safety functions. Disruption in the electrical power supply of HABOG might lead to malfunction of systems and controls. However all systems required for supporting the safety functions have a passive safety design. All other processes are designed to shut down in a safe manner following a large grid disturbance. This paragraph is further covered by chapter 5 (Loss of electrical power).

6.8 Failure of systems by introducing computer malware

Computer malware can possibly lead to failure of the overall control system (software/hardware). The function of this system is monitoring and alarming concerning the handling of radioactive waste. The direct control of the process, like the transport and handling of radioactive waste, needs manual interference. Failure of the control system can therefore not influence the fundamental safety functions.

6.9 Internal flooding

In chapter 3 (external) flooding is already discussed. The main conclusion is that flooding, due to the Westerschelde or by extreme rain fall, does not form a realistic threat to HABOG. This paragraph considers internal flooding, which can be caused by:

- Break of a main water pipeline

- Water from fire extinguishing.

If an internal flooding occurs, the water spreads across the floors and a localised build up may be possible. Due to the size of HABOG it will take considerable time before the water level significantly increases. Moreover, it is unlikely that large amounts of water are undetected in a short span of time. The ultimate consequence could be flooding of the waste storage and loss of electrical supplies. In chapter 3 it is evaluated that flooding of the waste storage will not result in a loss of fundamental safety functions. Loss of power is further covered by chapter 5.

7 Severe accident management

7.1 Organisation and arrangements of the licensee to manage accidents

7.1.1 Organisation of the licensee to manage the accident

COVRA, the organization which includes the HABOG facility, employs 58 people. About a quarter of these work in shifts, the others during office hours (Monday to Friday from 8.30 to 17.00). Occasionally activities outside office hours take place in the office, maintenance and/or production, or at information sessions and tours.

COVRA is organized according to the scheme presented in Figure 7.1

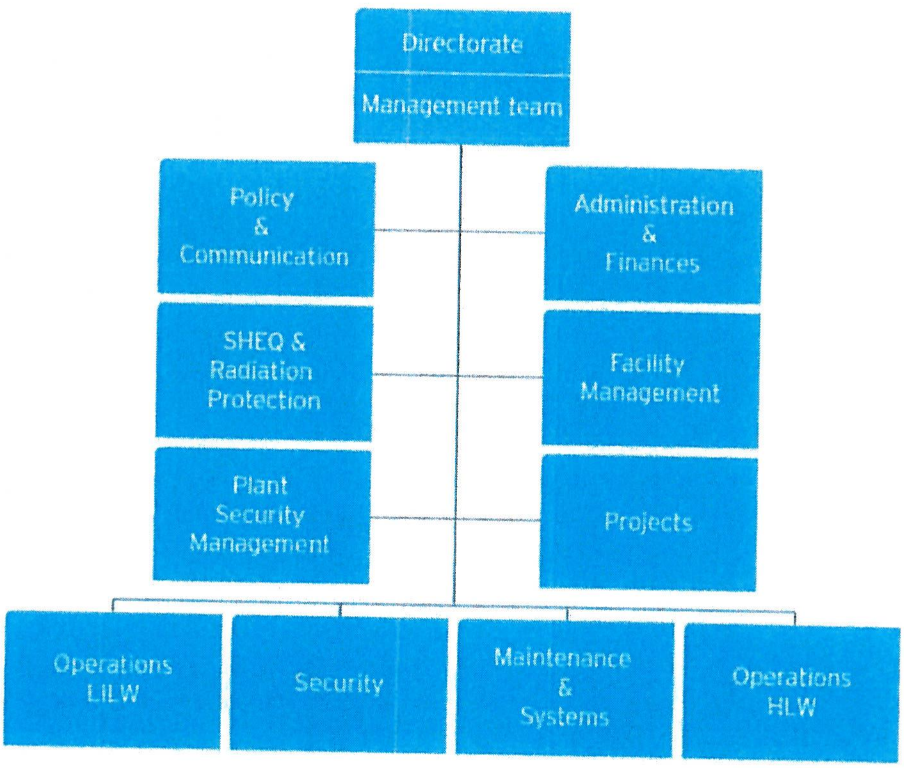


Figure 7.1 Organisation chart of COVRA

Emergency Plan

The emergency plan of COVRA (*Bedrijfsnoodplan*) specifies how its obligations arising from the Health and Safety Act (Arbo-wet) and the Nuclear Energy Act (KeW vergunning) are included within its organization. The emergency plan is tuned to the national emergency organization as is defined in the National Plan Nuclear Emergency Response (Nationaal Plan Kernongevallenbestrijding).

The emergency plan is a description of the organization, procedures and measures, taken by COVRA to minimize the consequences of an incident or calamity. The plan contains procedures, roles and most responsibilities of crisis team members and authorities that should be contacted in case of crisis. This concerns incidents or emergencies that can reasonably occur at the COVRA site.

The crisis team (CT) is formed in case of incidents involving more serious consequences such as serious personal injury, material damage, environmental damage (e.g. emission above authorized limits) or damage concerning public relations.

Presence and organization of emergency response fighters

At least 20 people of COVRA are trained as emergency response fighters (BHVs), so during office hours in general sufficient BHVs are present. Outside office hours at least one operator (BHV) is present in the central control room of COVRA (located in the AVG building). In case of deviations from normal operation or emergency situations he can call for other BHVs and external security guards, who are in consignation. When necessary, the BHV is supported by specialists for i.e. radiation protection. In case the central control room of COVRA cannot be used, the control room in the HABOG building is available as an alternative (due to the passive safety functions in HABOG, no remote control room outside the COVRA site is deemed necessary).

The BHV organization ensures the coordination and execution of the emergency services in case of incidents and/or accidents. The BHVs will give assistance to the emergency services. The BHV organization is led by the head or the deputy head of the BHV.

Access for emergency services

In case of incidents or accidents the main entrance of the COVRA site is accessible via the normal entrance (the main entrance and the entrance at the secured area). For COVRA, the following arrival times are used:

- Fire brigade 10 minutes
- Police 15 to 30 minutes

- Ambulance 15 minutes.

Communication during incidents and / or accidents

The central control room is the central point from which the emergency response is coordinated. The authorities will contact the central control room or the (deputy) head BHV.

Training, Exercise and Testing

Education and training are necessary within the emergency response organization (*BHV organisatie*). For this, courses and training programs are being followed. The resulting skills are practiced regularly.

The emergency response fighters (*BHV*) are trained for various emergency situations (firefighting etc.). An important part of the training is the support of external assistance (e.g. guidance for the fire brigade).

The head BHV is responsible for the training and exercise program to be initiated and carried out. This training program is designed to ensure that all required skills are trained and tested. The results of the exercises are evaluated and measures for improvement are suggested.

7.1.2 Possibility to use existing equipment

For HABOG the safety functions applicable to the facility and their operation are confinement and cooling of the waste and control of sub-criticality. All systems required for supporting the safety functions have a passive safety design. As a result, power supplies are not essential for maintaining the facilities safety (see section 5). So compared to an NPP no provisions for emergency situations are necessary.

In this section the available means and facilities for emergency situations are described.

Emergency Response Resources

COVRA has several emergency response resources, like fire-fighting tools and personal protective equipment that can be used to fight a calamity in and around HABOG. The equipment in the HABOG building consists of standard fire fighting extinguishers.

Equipment emergency organisation

The staff of the emergency response organisation can extend over the entire premises of COVRA. However, in order to achieve a rapid deployment with the right tools in case of emergency, BHVs and first aid posts are divided over the area according to the fire brigade emergency plan. The location of the posts is determined in such way that the whole area can be controlled and adjusted to the specific risks of that location.

At COVRA sufficient resources such as fire extinguishers, means of communication and first aid equipment are available to make effective actions of the BHVs possible. This equipment is inspected and maintained on a regular basis. At various places in the facilities signs are placed with instructions for accident situations and escape routes.

Fire-extinguishing arrangements HABOG

HABOG is equipped with a sprinkler system in the room with the emergency diesel day tank. These systems start (and stop) automatically in case of occurring fire but can also be operated manually.

In addition various types of extinguishers are present (foam and CO_2) inside the building. HABOG is not equipped with hose reels.

Firewater supply outside the buildings

The firefighting water is supplied by surface hydrants. The surface hydrants are connected to a fire extinguishing pipe network. The pipe network is fed with water from the firewater pond (contents: 10,000 m^3). It is also possible to use water from the firewater pond directly.

Fire alarm system

The central control room (24/7 occupied) is equipped with a fire control panel for HABOG. If a fire alarm in HABOG is given, the room from which the alarm was initiated is shown on the control panel.

HABOG has a fire panel (Mimic) near the entrance. When entering the building it can be noticed at what room the fire alarm was given.

Forced ventilation system in HABOG

The ventilated air of the different rooms is, finally, discharged through absolute filters. This air is monitored for the presence of radioactive materials.

The existing fire dampers are closed automatically when addressing a fire alarm. The fire dampers can be closed from the HABOG control room as well as locally.

7.1.3 Evaluation of factors that may impede accident management and respective contingencies

When the emergency plan at the COVRA site is actuated, the crisis centre in the central control room will be used. In the crisis centre divers (communication) facilities are available. The COVRA site (Spanjeweg) can be reached by road transport. The main roads N254 (from west direction) and N62 (from east direction) are at a distance of about 3 km from the site. The COVRA site can be approached by water transport from the Van Cittershaven/Kaloothaven at the north of the site and via the Westerschelde from the south-west. Access to HABOG is also possible by railway, coming from the south (Europaweg Zuid). So several alternative routes to reach HABOG are available when obstacles or damages may block normal access routes to the site. When routes over land are impossible, alternative ways are possible via air (a helicopter can land on the roof of HABOG) and water (boat).

After finishing (the necessary) operations in the facility, it is not needed to monitor and control the safety functions confinement, cooling and subcriticality. The task of the emergency responders is to prevent for (more) accidental conditions (e.g. prevent spreading of fire) at the site.

Power supplies are not essential for maintaining safety (see section 5). However, in case of emergency situations extra portable dosimeters may be necessary e.g. due to empty batteries.

The responsibilities of crisis team members is not fully covered in the emergency plan. This may result in inefficiencies and extra time needed during crisis response.

7.1.4 Conclusion on the adequacy of organisational issues for accident management

COVRA, and therefore HABOG, has an emergency plan which can be scaled up for management by the crisis team. The site can be reached by alternative routes. COVRA has an emergency response organisation with sufficient means to fight different calamities. The emergency fighters are trained for various emergency situations. On this basis it can be concluded that the organisational issues for accident management are adequate. However, for strengthening the emergency organisation the following is recommended:

- Extend the number of "ready to use" portable dosimeters in and around HABOG

* Extend the emergency plan with a description of all, fully covering, responsibilities of crisis team members.

7.2 Maintaining the safety functions

7.2.1 Prevention of loss of containment integrity

In section 1.3.3 the principal controls and safeguards to prevent release of radioactivity are described. The fundamental safety principle for waste storage is to maintain containment at all times during normal operations and operate the facility so as to minimize the potential for a release in fault conditions. Any discharges are filtered and monitored before release through authorized routes to the environment.

7.2.2 Prevention of loss of cooling

The principal controls and safeguards to prevent loss of cooling are described in section 1.3.2. The stack (air outlet) has a breaking point which, in case of a break, results in an acceptable stack height regarding thermal aspects. In a situation in which the air inlet is blocked, limit temperatures will not be exceeded within several months. Enough time will be available to restore the postulated situation.

7.2.3 Prevention of criticality

The principal controls and safeguards to prevent criticality are described in section 1.3.1. Due to the type, amounts of waste stored and the design of the storage equipment, occurrence of criticality is practically eliminated.

7.2.4 Conclusion on the adequacy of severe accident management systems for maintaining the safety functions

In relation to confinement, cooling and subcriticality control of the high radioactive waste, the design of the equipment, the facility installation and the operation of the facility shows to be adequate. The emergency response organization is prepared and equipped in case of accident conditions.

7.3 Accident management measures to restrict releases

The emergency plan of COVRA (*Bedrijfsnoodplan*) addresses accident categories. For the category of extreme events, such as airplane crashes, flooding, external fire, explosions etc. the following management measures are described.

The municipal emergency plan of the municipality Borsele immediately enters into force according to the National Plan Nuclear Emergency Response (Nationaal Plan Kernongevallenbestrijding). The Crisis Team therefore immediately informs the mayor of Borsele. In consultation further actions will be taken. At the COVRA site sufficient resources, such as fire extinguishers, means of communication and first aid equipment are available to make effective actions of the emergency fighters (BHVs) possible. The emergency plan describes at what locations emergency equipment is available.

No specific accident management measures are defined in the emergency plan to restrict radioactive releases from HABOG, nor are these deemed necessary.

7.4 Measures which can be envisaged to enhance capability to maintain safety functions and restrict releases

The following measures are recommended to enhance the capability to maintain safety functions and restrict releases:

- Extend the number of "ready to use" portable dosimeters in and around HABOG
- Extend the emergency plan with a description of all, fully covering, responsibilities of crisis team members.

Abbreviations

ADR	Accord européen relatif au transport international des marchandises Dangereuses par Route
AVG	Waste treatment building COVRA (afvalverwerkingsgebouw)
BDBA	Beyond Design Base Accident
BDBE	Beyond Design Base Eartquake
BDBF	Beyond Design Base Flood
BNP	Emergency Plan (Bedrijfsnoodplan)
COVRA	Centrale Organisatie Voor Radioactief Afval
DBA	Design Base Accident
DBE	Design Base Earthquake
DBF	Design Base Flood
GKN	Common NPP the Netherlands (Gemeenschappelijke Kernenergiecentrale Nederland)
HABOG	Hoog radioactief afval behandelings- en opslaggebouw
HPW	Heat Producing Waste
NBP	Nuclear base level (Nucleair BasisPeil)
NOP	Nuclear design level (Nucleair OntwerpPeil)
NPP	Nuclear Power Plant
non-HPW	Non-Heat Producing Waste (terms by COVRA: CSD-B and CSD-C)
KCB	Borssele Nuclear Power Plant (KernCentrale Borssele)
V-HPW	Vitrified fission products Heat Producing Waste (term by COVRA: CSD-V)
NAP	Mean sea level (Nieuw Amsterdams Peil)
NPP	Nuclear Power Plant
NVR	Dutch nuclear requirements (Nucleaire VeiligheidsRegels)
PGA	Peak Ground Acceleration
PSA	Probabilistic Safety Assessment
RR-HPW	Research Reactor Heat Producing Waste (term by COVRA: ECN canister)
SGN	Societe Generale pour les Techniques Nouvelles (France)
SSC	Structures, Systems and Components
UPS	Uninterrupted Power Supply

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NRG

List of tables

List of figures